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ABSTRACT A study was made of the foraminifera, diatoms, and radiolaria in bottom samples from the Gulf of California. Seventeen separate foraminiferal faunas are recognized, spanning the range from paralic facies to a depth of more than 3000 meters. Planktonic and benthonic foraminifera are more abundant than diatoms and radiolaria in sediments of the continental shelf and in the upper bathyal zone; radiolaria and diatoms are most abundant in sediments of the basin bottoms; radiolaria are relatively most abundant in the deepest basins at the south end of the Gulf. Sill depths appear to control the dominant distribution patterns of the basin assemblages.

Distribution of foraminifera, radiolaria and diatoms in sediments of the Gulf of California

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INTRODUCTION

Following the Huttonian philosophy that the present is the key to the past, it is basic that an understanding of modern geosynclinal deposition should be developed by examination and study of existing marine basins of deposition. One such basin is the Gulf of California, an elongate marine embayment about 700 miles long and 100 miles wide, which borders the western coast of northern Mexico and is separated from the Pacific Ocean by the peninsula of Baja California (text-fig. 1). This report will present generalized evaluations of faunal trends, principally foraminiferal trends, obtained by study of about 160 cores and snapper samples collected in the Gulf of California by cruises of the Scripps Institution of Oceanography in the years 1939 and 1940, and by cruises of *Velero IV* of the University of Southern California over a period of years. Sampling density is inadequate and preserved faunas were not available; however, a first step should be taken by evaluating available data; subsequent studies may then fill in the needed details and add to the fund of information.

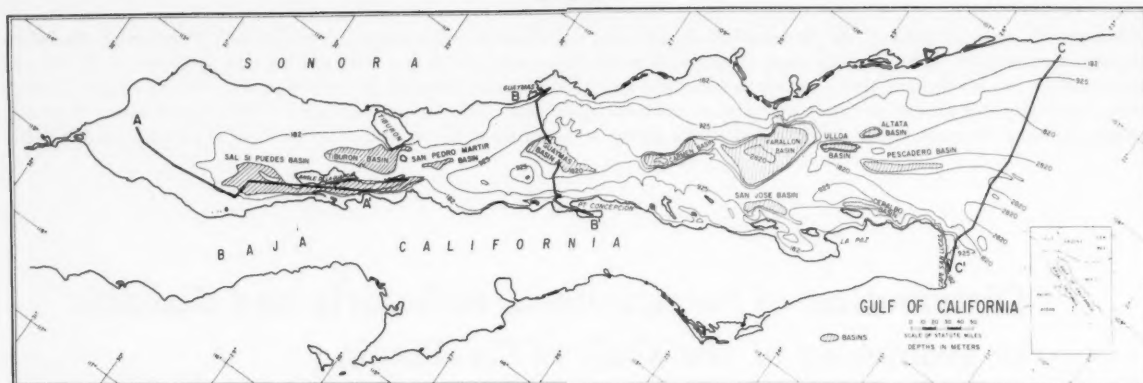
The Gulf of California occupies the principal portion of the Gulf of California geosyncline. The geosyncline may be conveniently subdivided into four depositional units. The first and northernmost unit is the Imperial Valley region, occupied by the Salton Sea and filled with some 20,000 feet of Cenozoic sediment resting on an igneous and/or metamorphic basement (Dibblee, 1954). In this northern unit approximately the upper half of the Cenozoic sediments are non-marine. Marine strata of late Miocene and Pliocene age, the Imperial formation, likely comprise the major portion of the remaining

stratified rock section below. This northern division of the geosyncline is nearest the source of sediments and the subsidence and depositional rates have been approximately equal since the late Miocene or early Pliocene. R. E. Arnal (1957) completed a thorough study of the sediments, limnology, and microorganisms of the Salton Sea, which occupies the central depression of this province.

A second province or division of the geosyncline is the head of the Gulf of California extending southward to Tiburon Island. The Colorado River delta and the Sal Si Puedes Basin are the significant features of this division. A third province embraces the central portion bounded by Tiburon Island at the northern end and the southern boundary of Farallon Basin, which is about the latitude of La Paz. Basins of this third division are deep, ranging from 2200 to about 3500 meters, and the bottom sediments contain abundant diatoms and radiolaria. The fourth province is the southern portion extending south from the Farallon Basin to the open end of the Gulf. Basins of this province are generally the deepest ones within the Gulf, attaining a maximum of about 3600 meters, and the sediments of the basin bottoms are dominated by radiolaria rather than foraminifera and diatoms.

The marine geology and oceanography of the Gulf of California has been the subject of a number of recent papers. A study by Byrne and Emery (1960) is based on a majority of the same samples used in the present study. In this and an earlier report by Byrne (1957) there is a detailed discussion of the history of exploration

BANDY



TEXT-FIGURE 1

Location of the Gulf of California and general bathymetry showing basins as crosshatched areas.

of the region, the regional geology, oceanography, sedimentation, and tectonics. Roden (1957) has also presented a recent report on the oceanography of the Gulf. Extensive earlier reports on the Gulf of California were made in 1950 by C. A. Anderson, Burham, Shepard, Natland, and Revelle. In these studies little information was included on the distribution patterns of modern microorganisms. Natland in a later study (1957) discussed the tolerance of *Bolivina vaughani* Natland to the varying conditions under which it occurs in the Gulf of California.

ACKNOWLEDGEMENTS

Grateful acknowledgment is made to the Shell Development Company, Houston, Texas, for providing financial support for the drafting, preparation of figures, typing and other expenses involved in preparation of this manuscript. Thanks are due the Scripps Institution of Oceanography for providing many of the samples and to the Allan Hancock Foundation for the remainder. Mary E. Taylor drew the figures of foraminifera. Gratitude is also expressed to K. O. Emery, University of Southern California, for his helpful criticism and suggestions; and to Johanna Resig of the Allan Hancock Foundation for her criticism of the manuscript.

METHODS

Laboratory and faunal analyses follow the rather standardized procedures as described in a number of articles (Bandy and Arnal, 1957). Briefly, each sample was weighed dry and washed on a 250-mesh Tyler screen (0.061 mm. openings). Carbon tetrachloride was then used for floating the tests of foraminifera. A modified Otto microsplitter was used to obtain representative fractions of each sample concentrate for percentage counts.

FORAMINIFERAL NUMBER

Schott (1935) originally defined foraminiferal number as the total number of foraminiferal specimens, benthonic and planktonic, contained in one gram of dry sediment.

This number is a valuable expression in that it may be applied equally to modern or ancient sediments. As a measure of abundance it reflects generally highest values on the outer shelf and in the upper bathyal zone, except for deep water planktonic oozes.

Foraminiferal numbers of more than 100 are common along the outer shelf areas and in the upper bathyal zone of the Gulf of California (text-fig. 2). Within these areas, delineated by the isopleth for 100, occur some individual samples with values of several thousand. It is important to note that values for foraminiferal number decrease toward the shore and into deeper waters.

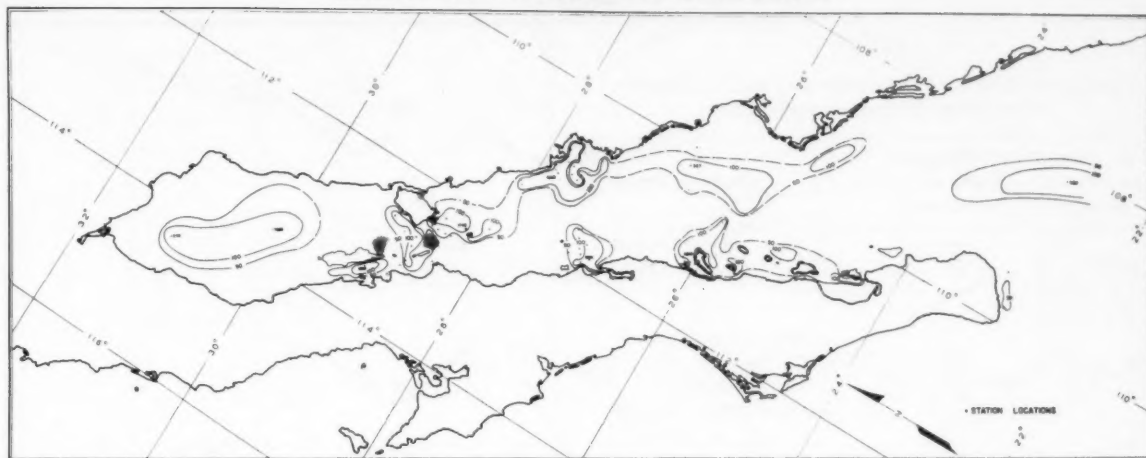
SPECIES NUMBER

Species number, the total number of species noted at each location within the Gulf of California, attains its highest values on the outer shelf and within the bathyal zone (text-fig. 3). Number of species was determined from the fractions counted, not from large unlimited samples. The total number of species could be increased by analysis of very large samples; however, by using a uniform approach it is considered that the same trends would generally exist in either case. Abundant species occur on the inner shelf in places along the western side and near Guaymas on the eastern side of the Gulf.

BENTHONIC POPULATIONS

A lack of preserved faunas is of course a serious drawback to a correct understanding of the distribution patterns of living benthonic populations. However, according to comparative studies of live and dead assemblages by Walton (1955) and the members of the Allan Hancock Foundation staff, it is apparent that steps may be taken to materially minimize the major difficulties of an approach using only empty tests. Although tests of foraminifera are transported after death, the tendency is for the specimens to be carried into deeper water rather than the reverse. Thus, upper limits of dead assemblages are the same or deeper than the range for living populations.

MICROFAUNA OF GULF OF CALIFORNIA



TEXT-FIGURE 2

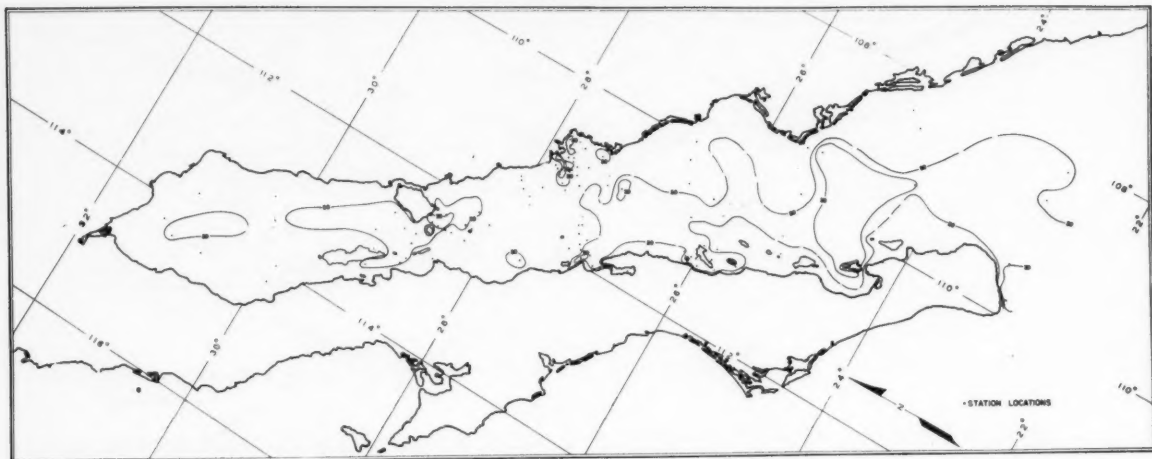
Foraminiferal number with values of 50 and 100 specimens per gram of dry sediment; figures with isopleths for 100 represent maximum values recorded.

Within the framework of the Gulf of California, sampling stations are representative of a vast array of environmental conditions. Conceivably, the upper limits of a given species may vary somewhat from one place to another. One important requirement is to determine the over-all depth ranges of dominant species within the Gulf. Hence all of the stations were arranged in order of increasing depth, regardless of location, in order that the generalized faunal depth zonation could be developed (Table 1).

Benthonic species of foraminifera are combined into seventeen faunas or biofacies which typify the following environments: a euryhaline fauna in lagoonal areas (Plate 1); a beach fauna in the intertidal zone (Plate 1); faunas 1 and 2 in the inner shelf zone (Plate 2); faunas 3 and 4 in the outer shelf zone (Plate 3); faunas 5, 6, and 7 in the upper bathyal zone (Plate 4); faunas 8, 9, and 10 in the upper middle bathyal zone (Plate 5); faunas 11, 12, and 13 in the lower middle bathyal zone (Plate 5); and faunas 14 and 15 in the lower bathyal zone (Plate 5). Continental shelf is used in place of the term sublittoral. Bathyal zone embraces the depths from 150 meters (the shelf-break) to about 4000 meters, which is generally in accordance with the usage in the Treatise on Marine Ecology and Paleocology (Hedgpeth, 1957). Benthonic faunas were established by arranging all species in order of appearance within the depth zones selected (Table 1 and text-fig. 4). Groups of species with similar upper limits of occurrence thus comprise faunas or biofacies. Total number of specimens of each species within each depth zone were then converted to percentage of the total benthonic population for each depth zone. Dominant species are considered to be those that total as much as 2 percent of the total population for any one of the depth zones. Rare species are not consistently present within a zone and they are not dependable indices.

As reported in the work of many others, there is a much more rapid transition from fauna to fauna across the shelf than in the bathyal zone. This rapid change in faunas across the shelf correlates with the rapid decrease in temperature and decrease in the annual range of temperature variation (text-fig. 4). It also correlates with a very rapid drop in the oxygen content from more than five milliliters per liter at the surface to less than one milliliter per liter at depths greater than 100 meters. Gradational changes in faunas of the bathyal zone are gradual and are parallel to a continued gradual temperature drop to about two degrees Centigrade in the deepest waters near the mouth of the Gulf. An oxygen minimum occurs between depths of 150 and 900 meters excepting in the northern area. According to Byrne and Emery (1960) this is due to the sinking of water with a high oxygen content because of increased density brought about by cooling and high evaporation.

An outstanding example of faunal displacement is to be seen in the lower middle bathyal zone where large numbers of Fauna 3, an outer shelf fauna, comprise more than 50 percent of the total population in the depth zone of Fauna 13, largely within the subsill portions of the Guaymas, Carmen and Farallon Basins. Estimates of displaced faunas (Table 2) reflect more than 70 percent displaced specimens throughout most of the Gulf. Evaluation of open slope as opposed to subsill basin values are not markedly different in the middle bathyal zone; however, there is a pronounced difference in the lower bathyal zone. In this zone the open slope has an estimated average of 39 percent displaced specimens whereas the Pescadero and Farallon Basins have averages of 70 and 100 percent displaced specimens, respectively. Additional samples and preserved specimens are needed to determine the true significance of these figures.



TEXT-FIGURE 3

Number of species of foraminifera with isopleths at 20 and 30 species.

VARIATION OF SHELF FAUNAS

It is apparent from the work of many authors that foraminiferal faunas vary somewhat in depth of occurrence from place to place (Parker, 1948; Bandy, 1953a, 1953b). A comparison was made of the inner shelf faunas of the east and west sides of the central area of the Gulf with those of the southern area (text-fig. 5A). In the three areas, the inner shelf population is the most abundant shelf assemblage amounting to 30 percent or more of the total fauna for any one station. In this inner shelf area outer shelf faunas (Fauna 3) comprise less than 7 percent of the total population, representing the total of rare occurrences of outer shelf indices in this upper zone.

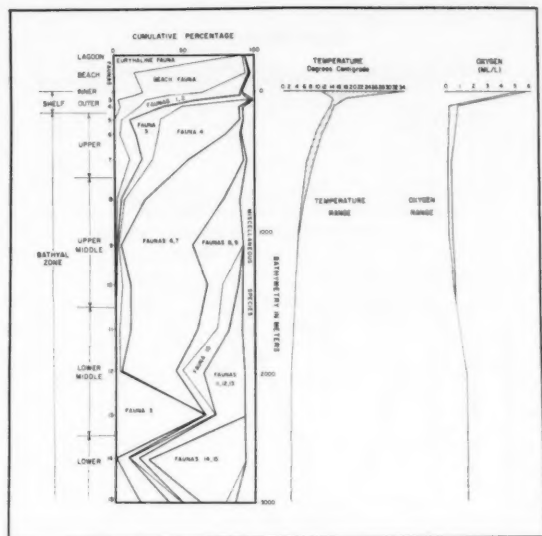
The outer shelf zone is characterized by somewhat more variation (text-fig. 5B) than in the inner shelf region. A pronounced deviation in proper faunal-zone identification occurs in the Colorado delta area. Inner shelf faunas represent the deepest dominant assemblage on the Colorado River delta in the outer shelf area. This is apparent in the frequency distribution at station 33 on the east side of the central area, a station within the outer part of the inner shelf zone. It would be difficult to distinguish between this inner shelf fauna and the assemblages of the outer shelf zone on the delta. The other samples of the profile on the east and west sides of the central province and in the Cape San Lucas area at the south end are entirely normal with a predominance of outer shelf faunas in the outer shelf zone. Perhaps the inner shelf faunas of the outer shelf area on the delta are relic faunas from the Pleistocene. However, this does not seem to be reasonable in view of the probable rapid depositional rate there for much of the post-Pleistocene interval.

PROFILE ANALYSES

Three profiles were selected to illustrate the general correlation of biofacies patterns with environmental conditions. The location of the profiles is indicated on text-figure 1 and consist of a northern longitudinal profile A-A', a central transverse profile B-B', and a southern transverse profile C-C'. The northern profile (A-A') extends from the northern end southward down the delta into the Sal Si Puedes Basin (text-fig. 6). Station G.47 is actually slightly below sill depth and it has a predominance of outer shelf faunas even though it is located at a depth of almost 400 meters which is within the upper bathyal zone. Upper bathyal faunas appear just below at station G.46 although not in great abundance. The remainder of the stations within the Sal Si Puedes Basin contain minor elements of the upper bathyal faunas which are generally indicative of sill depth. As was reported by Crouch (1952) and by Natland (1957), uniform conditions below sill depth of closed basins appear to favor the development of assemblages which identify the sill depth rather than the bottom of the basin. Resig (1958) found some zonation within the closed portion of the Santa Cruz Basin, off southern California, in her studies of preserved faunas. Thus, it would appear that the principal cause of uniform faunas below sills of basins might be displacement of these faunas into the basin, thereby masking the indigenous faunas. Displaced sediments and faunas are apparent in the Sal Si Puedes Basin where silty sands and shelf faunas occur. Foraminiferal number and the percentage of planktonic faunas are highest within the basin in this northern area.

Profile B-B', the central profile, extends from the mainland side near Guaymas across to Concepcion Bay on

MICROFAUNA OF GULF OF CALIFORNIA



TEXT-FIGURE 4

Cumulative percentage of benthonic foraminiferal faunas plotted against environmental trends of depth, temperature and oxygen (see Table 1).

the coast of Baja California (text-fig. 1). This profile crosses the Guaymas Basin and shows prominent shelf areas, steep declivities into the Basin, and a V-shaped bottom (text-fig. 7). Byrne reported slopes of 18 degrees on the northern side of the Guaymas Basin (1957). Well-developed inner and outer shelf faunas occur on both sides of the Gulf with a very rapid transition through upper bathyal, upper middle bathyal, to lower middle bathyal faunas in the central area of the Gulf. Some shelf faunas are noted in the bottom of the Basin, indicating displacement. Planktonic faunas and specimen abundance are greatest on the outer shelf and in the upper bathyal zone generally. Miliolid foraminifera attain dominant percentages in the inshore areas. The sill of this basin is less than 300 meters above the bottom of the basin and its effect is not detectable on the basis of the sparse sampling there.

Profile C-C' extends westward from the mainland side of the mouth of the Gulf to the region of Cape San Lucas at the southern end of Baja California (text-fig. 1). There is a remarkable difference between this profile and the preceding one. In the southern profile (text-fig. 8) there is a well-developed shelf sequence on the western side (C') which gives way abruptly to lower bathyal faunas in the central area of the Gulf, due to the very abrupt declivity from the shelf into deep bathyal waters there. A more gradual declivity on the eastern side (C) introduces a more gradual transition through upper bathyal faunas. The transition appears to have little dependence on the character of bottom sediments. Shelf faunas change with depth, temperature,

TABLE 2

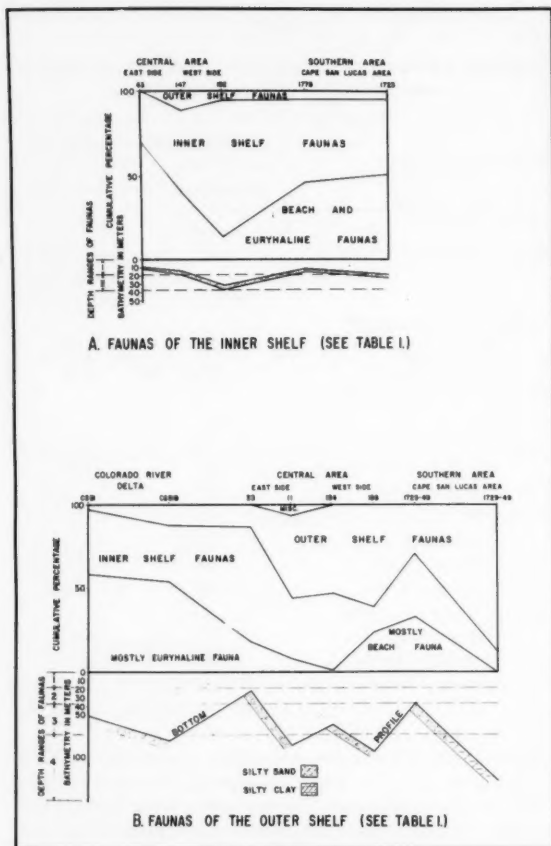
AVERAGE VALUES FOR DISPLACED FAUNAS IN PERCENTAGE ACCORDING TO DEPTH CATEGORIES

DEPTH CATEGORY	PERCENTAGE OF DIS-PLACEMENT	FAUNAS AS-SUMED TO BE DISPLACED
INNER SHELF	0	
OUTER SHELF	49	Euryhaline, Beach and nos. 1-2
UPPER BATHYAL ZONE		
Open slope	70	1-4
Tiburon basin	91	1-4
MIDDLE BATHYAL ZONE		
UPPER		
Open slope	76	1-7
Sal Si Pudes basin	73	1-7
Farallon basin	72	1-7
LOWER		
Open slope	83	1-10
Carmen basin	88	1-10
Guaymas basin	90	1-10
LOWER BATHYAL ZONE		
Open slope	39	1-13
Pescadero basin	70	1-13
Farallon basin	100	1-13

and distance from shore, regardless of the more or less continuous sandy bottom character. Bathyal faunas change with depth and temperature, regardless of the apparent uniformity of a mud bottom. Planktonic species are most abundant near the steep declivity on the western side of the Gulf. Porcelaneous species, primarily miliolids, are very abundant in the inshore waters of the western side in the vicinity of Cape San Lucas. Abundance of specimens (foraminiferal number) is greatest in the central area of the Gulf; however, it is doubtful that this value is significant, inasmuch as it represents only one sample.

DIATOM-FORAMINIFERA-RADIOLARIAN COMPLEX

Analyses of dominant microorganisms were based upon numbers rather than weight. The number of specimens per gram of dry sample was determined for diatoms, foraminifera, and radiolaria. Relative abundance of the three groups illustrate interesting relationships to the topography of the Gulf of California (text-fig. 9). Foraminifera amount to more than 50 percent of the total diatom-foraminifera-radiolaria complex in sediments of most of the northern province of the Gulf, on most of the continental shelf areas, and over large portions of the bathyal zone. Diatom frustules exceed 50 percent of the complex in most of the basin bottom sediments, from Sal Si Pudes Basin in the north to Farallon Basin in the south. Diatoms also attain dominance in shallower bathyal waters in many places, especially just below the edge of the shelf. As reported by



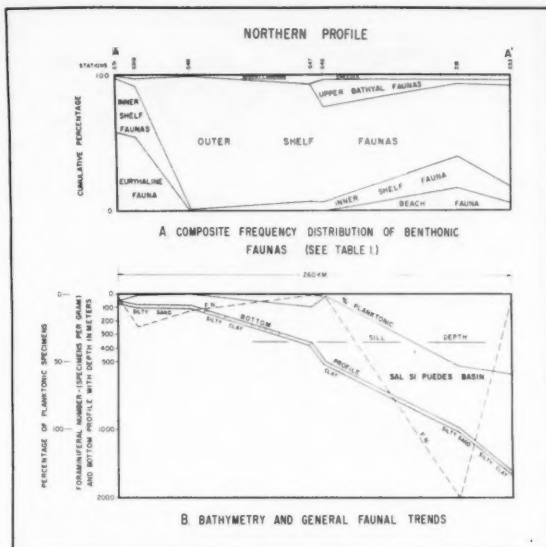
TEXT-FIGURE 5

Geographic variation of inner and outer shelf faunas within the Gulf of California.

Byrne and Emery (1960), the flowering of diatoms occurs principally in shallow waters of the Gulf, but they are deposited mostly in the deeper basins.

Radiolaria attain abundances of 50 percent or more of the diatom-foraminifera-radiolaria complex in the deeper portions of the southern province and locally around some of the basins of the central province. A transitional category is recognized for areas in which none of the three members of the complex amount to as much as 50 percent of the total. It is significant that transitional areas are very restricted; mostly there is a dominance of one of the three members of the complex.

Relative abundances of diatoms, radiolaria and foraminifera depict the dominant biota of the Gulf of California; however, the diatoms are so abundant that they tend to mask the trends of the radiolaria. A plot of radiolarian abundance demonstrates that maximum values of about 5200 specimens per gram occur in the Carmen-Farallon Basin area with decreasing values to the north and south (text-fig. 10). This area of abun-



TEXT-FIGURE 6

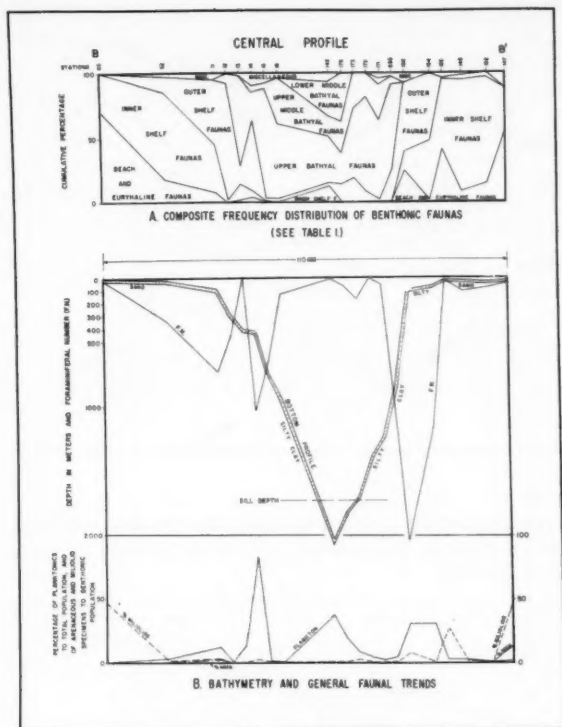
Faunal trends plotted against environmental changes along a north-south profile extending across the Colorado Delta into the Sal Si Pudes Basin (see text-figure 1, profile A-A').

dance is masked by the tremendous numbers of diatoms in the plot of the entire complex of diatoms-foraminifera-radiolaria (text-fig. 9). Radiolaria become relatively rare toward the open end of the Gulf; however, they are more abundant than either the diatoms or foraminifera there in the deepest waters.

PLANKTONIC FORAMINIFERA

Planktonic foraminifera are generally sparse or absent in inshore waters, compared with benthonic species. Among the foraminifera, percentages of planktonic specimens are highest on the outer shelf and in the upper bathyal zone for the most part (text-fig. 11). These are also less abundant in the southern half of the Gulf on the east side (wet side) than on the west side (dry side). Planktonic specimens comprise between 5 and 20 percent of the total foraminiferal specimens in several places on the western shelf in the southern half of the Gulf. They are very rare or missing from wide areas of the eastern shelf. The southeastern part of the Gulf is characterized by considerable rainfall and very marked variations in salinity may occur there in the shelf waters. Planktonic species are stenohaline and they would be excluded from such areas for this reason. A second feature of importance is the almost complete lack of planktonic specimens in the Colorado delta region at the north end of the Gulf. According to the salinity data of Byrne and Emery (1960), the waters of this region range from 35.5 parts per thousand at the surface to 34.8 parts per thousand at the bottom. There is little inflow from the Colorado River so that the delta area

MICROFAUNA OF GULF OF CALIFORNIA

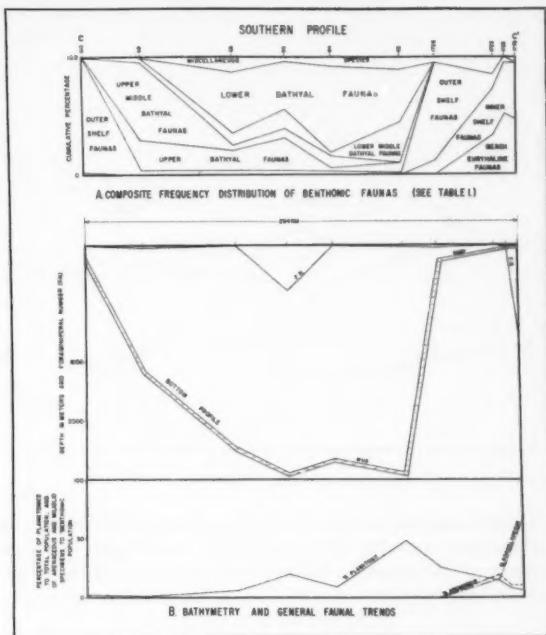


TEXT-FIGURE 7

Faunal trends plotted against environmental changes across the central portion of the Gulf of California (see text-figure 1, profile B-B').

is not characterized by a widespread brackish-water zone as about the Mississippi River debouchment. Perhaps the planktonic species are missing because of the lower temperatures at the north end. A surface water temperature range of 14° to 17° C. has been noted in the waters at the head of the Gulf; a range of 17.8° to 33.3° C. is reported near Guaymas; and a range of 11.1° to 36.7° C. is recorded near La Paz (Byrne, 1957).

Planktonic species may be conveniently subdivided into the three groups; a cold water *Globigerina pachyderma* fauna; a eurythermal *Globigerina bulloides* fauna; and a warm water *Globorotalia menardii* fauna (Table 3). Categories are generally patterned after those of Waller and Polski (1959) and Bradshaw (1959). The planktonic species are plotted according to depth. Even though these species are not bottom dwellers they do show a succession of appearance with increasing depth in the bottom sediments. It seems reasonable to assume that the planktonic species are variable in their amount of tolerance for environmental variation; thus, their numbers decline toward the more variable inshore waters. Notwithstanding his statement to the contrary, Bradshaw's data (1959) show a similar trend which



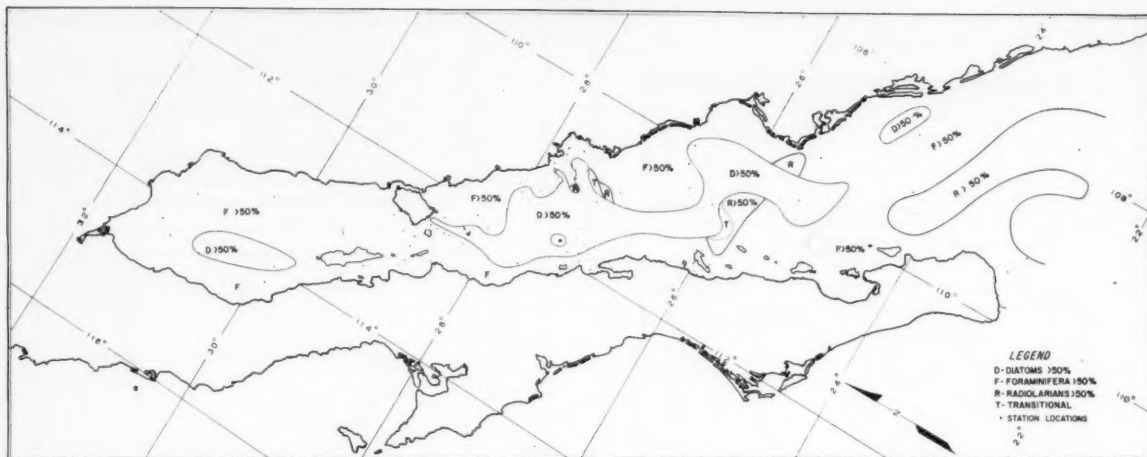
TEXT-FIGURE 8

Faunal trends plotted against environmental changes across the southern part of the Gulf of California (see text-figure 1, profile C-C').

more or less agrees with the succession of appearance reported earlier (Bandy, 1956; Bandy and Arnal, 1957). Species of *Globigerina* are most common in the shallow waters of the inner shelf although they amount to less than 10 percent of the foraminifera there. A few small specimens of *Globorotalia menardii* appear in the inner shelf populations.

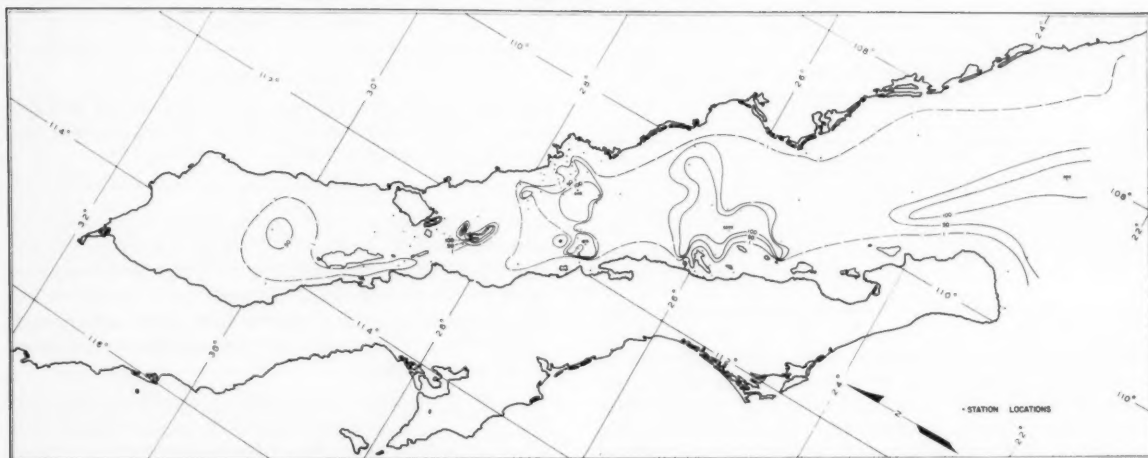
Diverse planktonic forms, nine species, occur in sediments from waters deeper than 18 meters, and *Pulleniatina obliquiloculata* appears below depths of 73 meters. Generally, planktonic specimens comprise less than 7 percent of the assemblages on the inner shelf, about 13 to 15 percent on the outer shelf, 14 to 37 percent in the upper bathyal zone, and highly variable values in deeper waters.

Tropical globorotaloids characterized by *Globorotalia menardii* show a much more restricted occurrence than the tropical globigerinids (text-fig. 12). Tropical or warm water globigerinids occur throughout the Gulf of California; *Globorotalia menardii* occurs in the central and western parts of the southern province, in the central and western parts of the central province, and across most of the Gulf just south of Tribuon Island. A few local patches of *Globorotalia menardii* are found on the east side near Guaymas. None occur in the northern province of the Gulf, as represented in the present samples.



TEXT-FIGURE 9

Relative abundance of the diatom-foraminifera-radiolarian complex within the Gulf of California. Symbols represent dominant member of the complex based upon the number of individuals. The symbol "T" indicates areas in which none of the three members comprises as much as 50 percent of the total.



TEXT-FIGURE 10

Radiolarian number with isopleths at 1, 50 and 100 specimens per gram of dry sediment. Maximum values recorded are indicated within the isopleths for 100.

Cold water globigerinids exceed 50 percent of the planktonic specimens in the Tiburon Basin, in patches along both the east and west sides of the Gulf of California in the central province, and in the deeper water sediments of the southern province. (text-fig. 13). *Globigerina pachyderma*, the principal species, is dominantly right-coiling throughout the samples. Maximum abundances of cold water globigerinids occur in the outer shelf waters and in areas of prominent upwelling. Both here and in the continental borderland waters off Southern California occur abundant representatives of this cold

water population. Eurythermal species are relatively common and they extend somewhat farther north into the delta area than the *G. pachyderma* fauna.

Throughout the Gulf, it was found that *Globigerina pachyderma*, *Pulleniatina obliquiloculata*, *Globigerina eggeri* and *Globigerina subcretacea* coiled dominantly dextrally, or in a right-handed manner. Left-coiling species included *Globorotalia menardii* and *Globorotalia tumida*. All other species appeared to have about equal numbers of left- and right-coiling members.

— • RANGE OFF SOUTHERN CALIFORNIA

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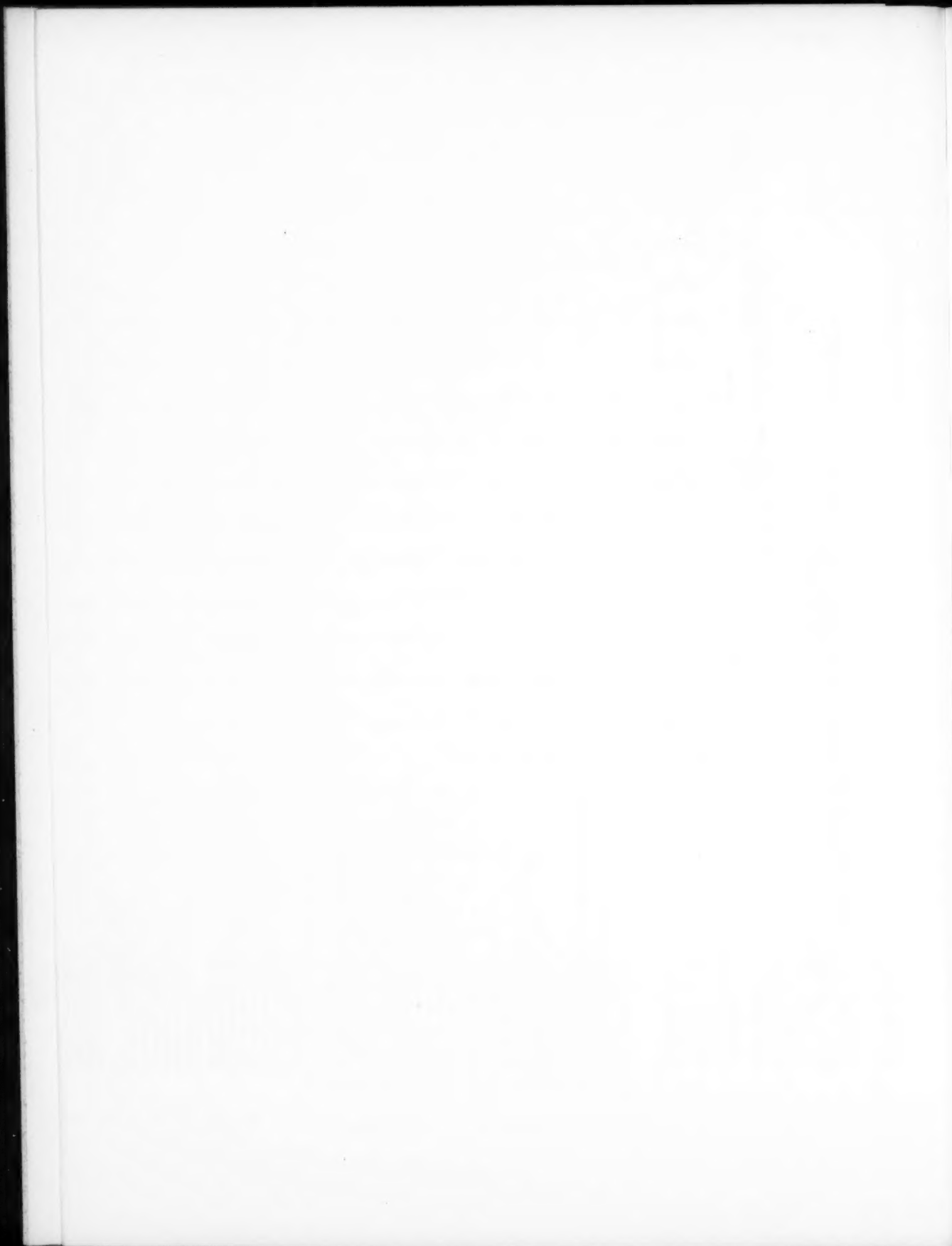
[illegible]

Z	I	3. 37-71 M. T. 12.5 to 18.0° C.									
		A. DOMINANT SPECIES									
		BOLIVINA ACUTULA	X	3	1	X	X	X	X	X	X
		BOLIVINA DENUATA	X	5	2	6	13	1	1	X	X
		BOLIVINA MARGINATA VAR.		2							
		BOLIVINA LAEVIGATA		9	3	2	1	1	1	1	7
		CASSIDULINA MINUTA		8	3	9	X	2	1	X	64
		CASSIDULINA MINUTA		3	2	X	1	2	X	1	
		CASSIDULINA QUADRATA		3	2	3	1	X	X	X	
		PLANULINA ORNATA									
V	A	B. OTHER SPECIES									
		ARCHAIA ANGULATUS	X								
		BOLIVINA GLOBULOSA	X								
		BOLIVINA TONGI	X								
		CANCERIS AURICULA	X								
		EPONIDES PSEUDOAFINIS	X								
		GAUDRYINA ATLANTICA	X								
		HANZAWAIA BERTHELOTTI	X								
		NONIONELLA CHILIENSIS	X								
		NONIONELLA DECORA	X								
		POLYMORPHINA SPP.	X								
		ROBULUS SPP.	X								
		SIGMOILINA TENUI	X								
H	A	4. 73-152 M. T. 10.0 to 12.5° C.									
		A. DOMINANT SPECIES									
		ANGULOGERRINA ANGULOSA	X	2	2	1	2	X	X	1	X
		BOLIVINA ACUMINATA	X	2	12	2	4	2	X	X	4
		BOLIVINA INTERJUNCTA	X	5	5	9	10	X	X	X	2
		CANCERIS PANAMENSIS	X	2	1	X	1	X	X	X	2
		EPISTOMINELLA BRADYANA	X	28	36	35	6	14	2	3	8
		EPISTOMINELLA BRADYANA	X	2	1	1	1	X	X	1	
		PLANULINA ARMINENSIS	X								
L	I	B. OTHER SPECIES									
		BOLIVINA PACIFICA	X	X	X	X	1	2	X	X	X
		BULIMINELLA CURTA	X								
		CHILOSTOMELLA OVIDEA	X								
		CIBICIDES MCKANNAI	X								
		EHRENBERGIA COMPRESSA	X								
		EPISTOMINELLA OBESA	X								
		GAUDRYINA ARENARIA	X								
		TROCHAMMINA GLOBIGERINIFORMIS	X								
		UVIGERINA INCILIS	X								
S	A	5. 152-244 M. T. 8.0 to 10.0° C.									
		A. DOMINANT SPECIES									
		SAME AS ABOVE									
Z	I	B. OTHER SPECIES									
		CASSIDULINA PULCHELLA	X								
		CASSIDULINA SUBGLOBOSA									
		PULLENIA INFLATA									
		VALVULINERIA INFLATA									
A	I	6. 244-364 M. T. 6.0 to 8.0° C.									
		A. DOMINANT SPECIES									
		BOLIVINA PULGATA									
		UVIGERINA PEREGRINA									
L	I	B. OTHER SPECIES									
		CASSIDULINA SUBCALIFORNICA									
		CASSIDULINOIDES TENUI									
		GYRODINA MULTIOCCULA									
		GYRODINA ROTHWELLI									
		UVIGERINA EXCELENS									
		VALVULINERIA INAEQUALIS									
L	I	7. 364-610 M. T. 4.5 to 6.0° C.									
		A. DOMINANT SPECIES									
		BOLIVINA SEMINUDA AND VARS.									
		BOLIVINA SPISSA									
		BULIMINELLA EXILIS TENUATA									
		CASSIDULINA CUSHMANI									
		CASSIDULINA DELICATA									
		CASSIDULINA TORTUOSA									
		CASSIDULINA TRANSLUCENS									
		EPISTOMINELLA EXIGUA									
		SUGGRUNDA ECKISI									
A	I	B. OTHER SPECIES									
		CASSIDULINOIDES CORNUTA									
		GLOBULIMINIA PACIFICA									
		GYRODINA ALTIIFORMIS									
		LOXOSTOMUM PSEUDOBRYCHII									
		UVIGERINA GALLOWAYI									
		VIRGULINA SEMINUDA									

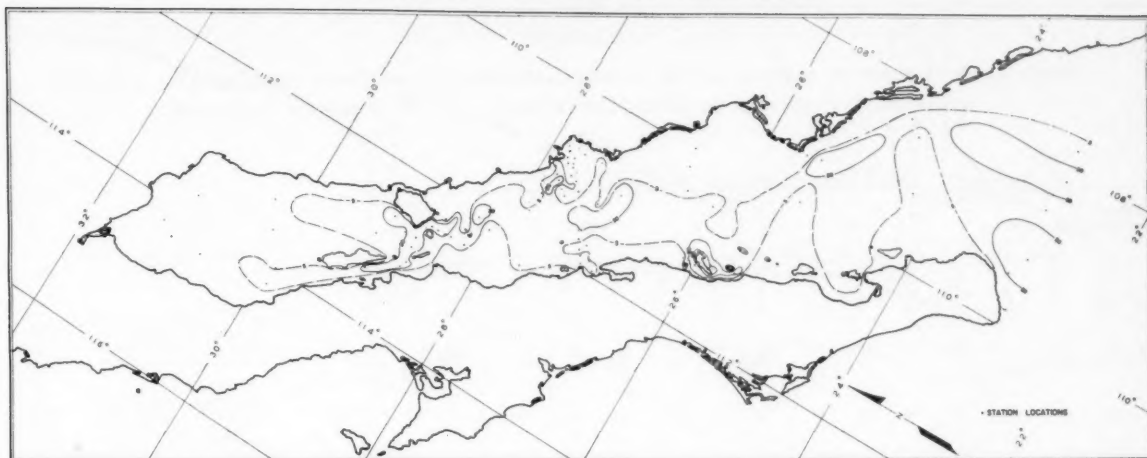
*Probably Fossil

TABLE 1

[illegible]

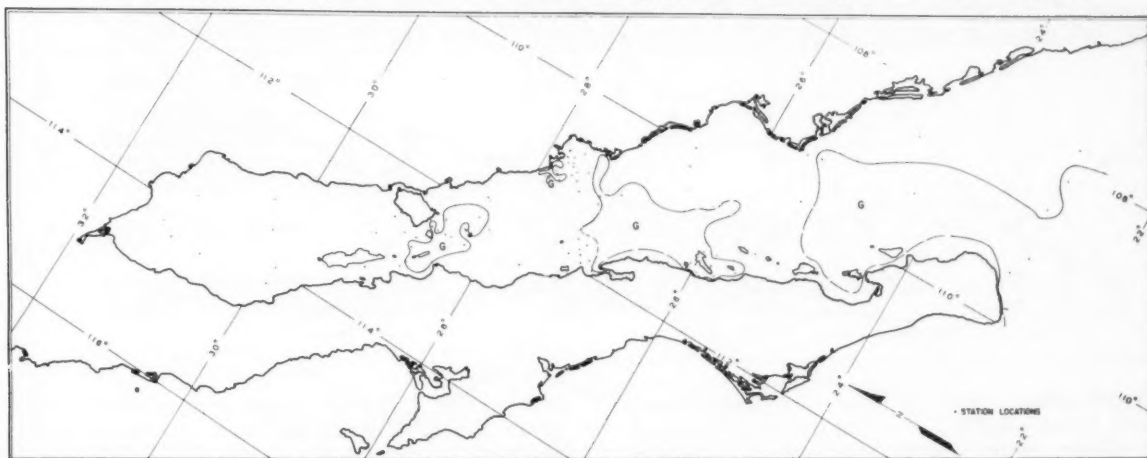


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TEXT-FIGURE 11

Percentage of planktonic foraminifera to total foraminiferal population, with isopleths at 5 and 20 percent.



TEXT-FIGURE 12

Occurrence of *Globorotalia menardii* within the Gulf of California.

PALEOECOLOGICAL IMPLICATIONS

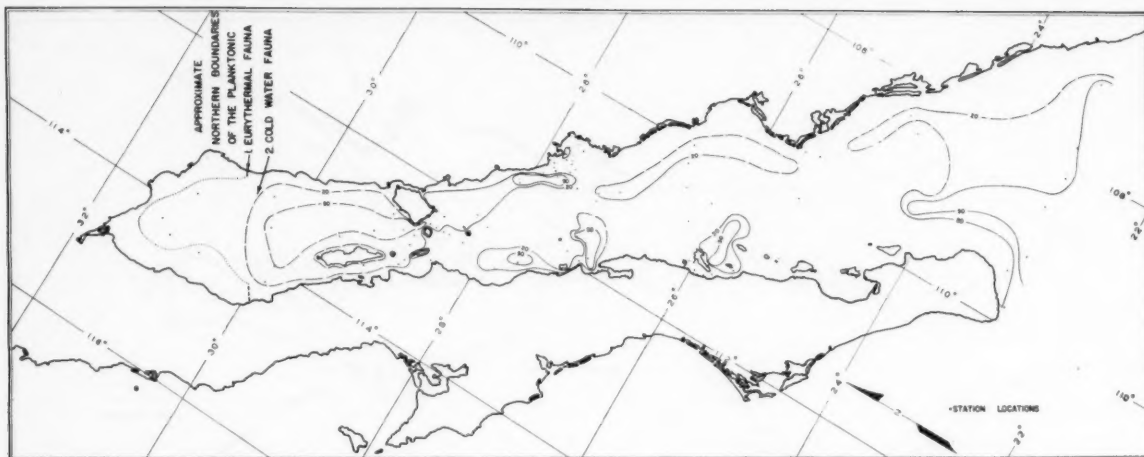
General Discussion

It is interesting to reconstruct the bathymetry of the Gulf of California based upon the depth ranges given in Table 1 and text-figure 14. Even though a minimum number of control points is available it is possible to outline the general framework of the basin. Biofacies intervals in the reconstruction were determined by selecting the upper limits of the deepest dominant fauna occurring for each station from the data in Table 1. Because of the gradational nature of faunas with depth, it was decided that the absolute upper limits of a given fauna should not be used. Instead, and after inspection of the data, the deepest water fauna, totalling more than 7 percent of the benthonic assemblage, was used in

assigning bathymetric ranges. This same general method was used in reconstructing the middle Tertiary sea of the San Joaquin Basin, California (Bandy and Arnal, 1960).

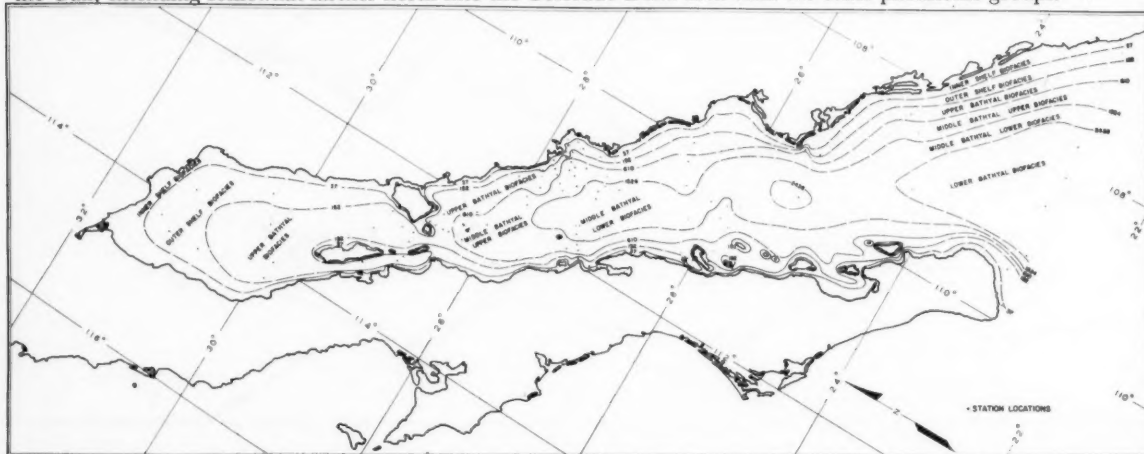
Major problems in such reconstructions involve the definition of subsill basin features and the recognition of localized basins which may not be detected because of sparse sample coverage. Errors of interpretation are very definitely toward the assignment of sill depths to basin deposits, and the identification of outer shelf deltaic deposits as inner shelf facies. In the reconstruction (text-fig. 14), it is apparent that sill depth control is a major problem. Pronounced closed basins such as the Sal Si Pudes basin are not revealed.

BANDY



TEXT-FIGURE 13

Occurrence of cold-water *Globigerina pachyderma* fauna sediments of the Gulf of California with isopleths at 20 and 50 percent of the total planktonic population. The eurythermal *Globigerina bulloides* fauna occurs more or less throughout the Gulf, extending somewhat farther north into the Colorado Delta area than the other planktonic groups.



TEXT-FIGURE 14

Reconstruction of topography based upon bathymetric faunal divisions (see Table 1). Contours represent approximate upper limit of each biofacies representing that bathymetric unit. Depths are indicated in meters.

Recognition of subsill deposits

Subsill assemblages are remarkably uniform (Crouch, 1952), due to two factors. Resig (1958) discovered zonation in living populations below the sill of the Santa Cruz Basin off the coast of southern California, although this was largely masked by the dead assemblages. Displacement of assemblages from sill depth and above is probably responsible for the masking effect. It is also possible that some species are adapted to the general subsill conditions, and, because of the anomalous environmental conditions, they are dwarfed. Dwarfed assemblages might be expected in subsill basin deposits of the geological past.

Ferruginous metabolism among the foraminifera was reported by Le Calvez (1951) for low oxygen environments in shoal nearshore marine environments. Isatchenko (1929) had earlier noted the development of pyrite crystals in sulphate-reducing bacteria. Subsill basin sediments contain muriform masses of pyrite which are considered to be the result of microenvironments with negative *Eh*, produced by the decomposing protoplasm of foraminifera, radiolaria and diatoms (Emery, 1960, p. 267). These features are reported in shelf sediments of near-shore areas where there is an abundance of organic material and reducing conditions

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TABLE 3

RELATIVE ABUNDANCE OF PLANKTONIC FORAMINIFERAL TESTS IN BOTTOM SAMPLES OF THE GULF OF CALIFORNIA.
(Abundance is expressed as percentage of total planktonic tests for each depth zone.)

LAGOONAL ENVIRONMENT	INTER-TIDAL ZONE	BATHYMETRIC ZONES WITH WATER DEPTHS IN METERS														
		S H E L F				U P P E R B A T H Y A L		M I D D L E B A T H Y A L				L O W E R B A T H Y A L		L O W E R B A T H Y A L		
		I N N E R		O U T E R				U P P E R				L O W E R				
		0-18	18-37	37-73	73-152	152-244	244-366	366-610	610-914	914-1219	1219-1524	1524-1829	1829-2134	2134-2438	2438-2743	2743 M
GLOBIGERINA PACHYDERMA FAUNA	PLANKTONIC SPECIES															
	A. COLD WATER SPECIES															
	GLOBIGERINA PACHYDERMA	20	1	3	12	15	22	20	21	40	23	42			60	97
	GLOBIGERINOIDES MINUTA		5	7	5	2	2	23	3	3	4	3	20	20		
GLOBIGERINA BULLOIDES FAUNA	B. EURYTHERMAL SPECIES															
	GLOBIGERINA BULLOIDES	73	37	32	24	40	28	23	33	29	28	21	33		20	14
	GLOBIGERINA EGGERI				1		X									5
	GLOBIGERINA GLUTINATA				11	8	14	18	20	1	7	5	9			
	GLOBIGERINA QUINQUELOBA		6	11	11	X	X	1					2			
	GLOBIGERINA SUBCRETACEA			2	X	X	1	1								2
GLOBOROTALIA MENARDII FAUNA	C. WARM WATER SPECIES															
	GLOBOROTALIA APERTURA				2	X	9	2	5		1					
	GLOBOROTALIA DRURYI				X	1										
	GLOBOROTALIA DUTERTREI	70	12	24	25	32	27	19	9	3	27	35	16	25	80	20
	GLOBOROTALIA HEXAGONA				1		1									
	GLOBOROTALIA CYCLOSTOMA				2						X		2			3
	GLOBOROTALIA CONGLOBATA				X		X	X								
	GLOBOROTALIA RUBRA			6	2	1	4	1	3	10		4	2			
	GLOBOROTALIA SACCULIFERA				5											
	GLOBOROTALIA TRILOCULARIS			3	1	X	X									
	GLOBOROTALIA MENARDII	10	15	17	7	4	2	1	1	3	X	3	2			8
	GLOBOROTALIA PUNCTULATA				1	X	X	X	2		X	4				2
	GLOBOROTALIA TUMIDA															4
	HASTIGERINA AEQUILATERALIS			1												
	ORBULINA UNIVERSA							X								1
	PULLENIATINA OBLIQUOLUCULATA				1	1	X	X				2	5			
	GLOBIGERINA INFLATA															
TOTAL PLANKTONIC SPECIMENS		10	26	79	376	295	340	523	1205	61	91	278	112	45	5	119
NUMBER OF SPECIES		3	3	9	15	15	10	15	13	9	5	9	9	9	2	11
TOTAL BENTHONIC SPECIMENS		231	159	761	1006	2122	1973	2070	1411	2067	1273	1349	788	919	125	14
TOTAL SPECIMENS		231	169	787	1085	2498	2268	2410	1934	3272	1334	1440	1066	1031	170	19
PERCENTAGE PLANKTONIC SPECIMENS		0	6	3	7	15	13	14	27	37	5	6	26	11	26	32

prevail (Shukri and Higazy, 1944; Le Calvez, 1951). It is possible that muriform fillings of bathyal microorganisms, on the other hand, are most characteristic of poorly oxygenated basin sediments. If so, this may be a corroborative tool in basin sediment recognition.

Recent studies of southern California basins show that finely laminated sediments occur only within the subsill areas of one basin where few benthonic organisms exist (Emery, 1960). An abundant benthonic population would continually destroy such laminations. Thus, microorganisms in finely laminated sediments should be largely those of planktonic and nektonic types. This may prove to be a significant criterion of subsill deposits.

Graded beds occur in basins and on the open sea floor. Such features cannot be evaluated properly unless the clay and sand layers are studied separately. Investigations by Hand (1959) of graded beds in the Pliocene sediments of the Ventura Basin shows the presence of bathyal foraminiferal populations in clay layers, and of shelf assemblages in the sand layers there. Thus, only the clay layers may contain the indigenous faunas which reflect the subsill environmental conditions.

Three-dimensional studies of former basin deposits should be an additional tool in defining subsill basin deposits. Faunas should change rather rapidly in sections away from a basin whereas the thick sections of subsill deposits should contain relatively uniform faunas. Very abrupt changes from basin to shelf facies occur across the steep scarps along the western side of the Gulf of California (text-fig. 8). Thus, basin slopes could very well separate almost entirely different benthonic faunas in similar patterns of the geological past. Planktonic foraminiferal species are identical on the two sides of the basin slope zone and should be of greatest value in stratigraphic correlation under these conditions. Radiolaria and diatoms, also planktonic groups, are of major importance in the basin bottoms although they also live in much shallower waters. Radiolaria and diatoms do occur near the edge of the shelf in a very few localities, especially near submarine canyons. Generally their abundance is not great in shallow waters. Radiolaria are oceanic animals and live throughout a long column of water, some living in deep bathyal parts of the oceans (Campbell, 1954). It follows that sediments below a long column of water

are more likely to have abundant radiolaria than otherwise. Diatoms, conversely, are plants that thrive in areas of upwelling in the Gulf, over the continental shelf. Their slow settling velocity results in their being swept clear of most shallow water areas of the Gulf and they finally come to rest in the deepest and quietest areas of the basins (Byrne and Emery, 1960) where they mask the relatively sparse foraminiferal populations.

Recognition of structural trends

Structural trends may be revealed by computing subsidence rates in well sections from a given basin (Bandy, 1953b; Bandy and Arnal, 1960). It is apparent that totally different benthonic assemblages dominate the basin assemblages within the Gulf of California. Northern basins are characterized by an abundance of shelf and upper bathyal assemblages; central basins are dominated by middle bathyal assemblages; and southern basins are characterized by lower bathyal assemblages. Reflecting upon geosynclines of the geological past, planktonic correlations might tie together basin populations which are quite unlike one another and thus direct attention to localized basins of development or negative areas within the larger geosyncline. The basin populations would be separated generally by structural trends.

Recognition of shelf trends

Near-shore areas with normal salinity (34⁰/₀₀) exhibit an abundance of miliolids, especially species of *Quinqueloculina*. Shelf sediments of the Colorado delta also contain an abundance of miliolids; however, a significant percentage of *Streblus tepidus* occurs here. From this and earlier studies (Bandy, 1954; 1956) it would seem that this species becomes dominant off the mouths of streams, rivers, and in lagoonal areas. It is a minor constituent of inner shelf faunas, except in areas which are subject to considerable variation in salinity. Its abundance in the delta area suggests much greater variation in salinity than has been recorded.

Abnormality of form was noted in some of the near-shore assemblages. Arnal (1955) reported on the occurrence of abnormal foraminiferal populations in lagoons, in the Salton Sea, and in other near-shore and brackish water areas. Foraminifera that show marked deviation from a symmetrical form in the present investigation include species of *Cibicides*, *Rotorbinella*, *Quinqueloculina*, *Elphidium*, *Streblus*, and others. Specimens of *Cibicides fletcheri*, *C. lobatus*, *Rotorbinella lomaensis*, and *Streblus tepidus* that are biserial were noted. It is likely that *Dycibicides*, a coiled and biserial type, is little more than an abnormal manifestation of several different forms (Gilmour, 1959). Specimens in beach faunas are typically considerably worn and broken.

Recognition of subsea fans

Emery (1960) has described the sedimentary character of subsea fans, indicating that contorted bedding, mud

clasts, and other features of mass movements from the upper parts of the slopes characterize these deposits. Zalesny (1959) has discovered a remarkable abundance of one foraminifer, *Bolivina argentea* Cushman var. *monicana* Zalesny, in the sediments of the subsea fans at the foot of both the Santa Monica and Redondo submarine canyons, off southern California. Sampling density failed to show similar faunal characteristics in basins of the Gulf of California. Faunal studies of subsea fans are needed in order to determine the true relationships of faunas to various types of fans.

COMPARISON OF GULF OF CALIFORNIA BIOFACIES WITH SELECTED EXAMPLES Moreno shale

The Moreno shale of California is an Upper Cretaceous (Maestrichtian) to Paleocene (Danian) rock unit exposed along the west side of the San Joaquin Valley, California (Payne, 1951). It contains an abundance of radiolaria and diatoms, and it has an extremely low foraminiferal number throughout parts of the section. The Danian age of the upper Moreno was recognized long ago (F. M. Anderson, 1943). Benthonic foraminiferal components include *Siphogenerinoides whitei* and *Bulimina proluxa* in the Upper Cretaceous (Maestrichtian) portion and *Valvulineria lillisi* and *Bolivinospis grzybowskii* in the basal Paleocene (Danian) (Martin, 1960). A Paleocene Danian age is indicated by the appearance of the planktonic species *Globigerinoides daubjergensis* and *Globorotalia pseudobulloides*. Benthonic species of foraminifera are isomorphs of modern bathyal species, abundant radiolaria of the Moreno include some that range up to about one-half millimeter, and diatoms are also rather characteristic. Bathyal foraminifera, together with the abundance of large radiolaria, suggest an accumulation within a basin comparable to the Guaymas and Carmen basins, or deeper ones. A lack of planktonic species of foraminifera is not indicative of shallow water deposition in this formation any more than in the modern basins of the Gulf of California.

Kreyenhagen shale

The Kreyenhagen shale of California ranges in age from middle Eocene (Lutetian) to late Eocene (Bartonian), and into the Oligocene in some sections. *Globorotalia aragonensis* and *Hantkenina dumblei* indicate a middle Eocene age for the lower part of the formation; *Hantkenina alabamensis* and *Globorotalia cocoensis* indicate a late Eocene age for the upper portion (Mallory, 1959). The laminated shales of the Kreyenhagen contain an abundance of bathyal species of foraminifera (Cushman and Siegfus, 1942). Many of these have modern isomorphs in the Gulf of California in the middle and lower bathyal zones. Species of *Osangularia*, *Bulimina rostrata* types, a form close to *Eponides tumidulus* known as *Valvulineria chirana*, and others illustrate the similarity. These, together with the abundance of diatoms and radiolaria, again suggest strongly that the Kreyenhagen shale accumulated in a deeper basin (or basins) within

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the San Joaquin embayment, separated from different kinds of upper and middle Eocene facies by structural trends comparable to those observed in the Gulf of California. Zones of rather large radiolaria occur within the Kreyenhagen, although they are far less important than the diatoms, from the standpoint of abundance.

SUMMARY AND CONCLUSIONS

The Gulf of California is about 700 miles long, 100 miles wide, and more than 3000 meters deep. Deep basins within the Gulf provide a highly diversified framework for the evaluation of biofacies patterns. General faunal trends include the following: maximum species diversity and foraminiferal numbers occur on the outer shelf and upper slope; benthonic and planktonic foraminifera are more abundant than diatoms and radiolaria in the sediments of the continental shelf and in the upper bathyal zone; radiolaria and diatoms are most abundant in the sediments of basin bottoms; radiolaria are relatively more abundant than diatoms and foraminifera in the deepest basins at the south end of the Gulf; porcelaneous foraminifera comprise more than 20 percent of the benthonic specimens of the inner shelf; malformed foraminifera are most common in inshore waters; and dwarfism appears to be most common in deep closed basins.

A total of 17 faunas or biofacies are established; one is characteristic of euryhaline conditions, a second is characteristic of the intertidal zone, and the remaining 15 are depth biofacies. The paralic and shelf species are divided into 6 biofacies (0-152 meters); the remaining 11 biofacies are bathyal divisions.

Deep basins with shallow sill depths have uniform assemblages reflecting sill depth. Inner shelf biofacies are dominant in the outer shelf of the Colorado delta; otherwise the inner shelf biofacies are only abundantly represented in the area of the inner shelf. Displaced faunas are common within the bathyal zone of the Gulf of California.

Prominent structural trends separate basins of the Gulf of California. Distinct and different benthonic biofacies characterize the various basins. Planktonic assemblages offer the primary common denominator in terms of correlation. In terms of paleoenvironmental significance, geologic formations such as the Eocene Kreyenhagen shale and the late Cretaceous-Paleocene Moreno shale are fossil counterparts of the deposits now accumulating in basins of the Gulf of California. These formations contain an abundance of radiolaria, diatoms, and bathyal foraminifera. They include finely laminated sediments indicating accumulation in the absence of prominent benthonic macrofaunas. Thus, it is probable that these formations also accumulated in basins within the San Joaquin Valley seaway. Such deposits would be separated from other facies of the same age by structural trends.

APPENDIX A - FAUNAL REFERENCE LIST PLANKTONIC SPECIES

- Globigerina apertura* Cushman, 1918, U. S. Geol. Survey, Bull., no. 676, p. 57, pl. 12, fig. 8.
- Globigerina bulloides* d'Orbigny, 1826, Ann. Sci. Nat., Foraminifères, Ser. 1, vol. 7, p. 277.
- Globigerina druyi* Akers, 1955, Jour. Pal., vol. 29, no. 4, p. 654, pl. 65, fig. 1.
- Globigerina dutertrei* d'Orbigny, 1839, in de la Sagra, Hist. Phys. Pol. Nat. Cuba, "Foraminifères," p. 84, pl. 8, fig. 4.
- Globigerina eggeri* Rhumbler, 1901, in Brandt, Nordisches Plankton, Ser. 1, no. 14, pp. 19-20, text-fig. 20.
- Globigerina glutinata* Egger, 1895, K. Bayer, Akad. Wiss., Math.-Physik Cl., Abh., vol. 18, pt. 2, pl. 13, figs. 19-21. *Globigerinita* is considered to be a junior synonym of *Globigerina*.
- Globigerina hexagona* Natland, 1938, California, Univ., Scripps Inst. Oceanogr., Bull., Tech. Ser., vol. 4, no. 5, p. 149, pl. 7, fig. 1.
- Globigerina inflata* d'Orbigny, 1839, in Barker-Webb and Berthelot, Hist. Nat. des Iles Canaries, "Foraminifères," vol. 2, pt. 2, Zool., p. 134, pl. 2, figs. 709.
- Globigerina pachyderma* (Ehrenberg) = *Aristospira pachyderma* Ehrenberg, 1861, K. Akad. Wiss. Berlin, Monatsber., pp. 276, 277, 303. *Globigerina bulloides* d'Orbigny var. *borealis* Brady, 1881, was considered by Brady to be a synonym with the earlier name of Ehrenberg. His conclusions are accepted and the earlier name of Ehrenberg is used.
- Globigerina quinqueloba* Natland, 1938, California, Univ., Scripps Inst. Oceanogr., Bull., Tech. Ser., vol. 4, no. 5, p. 149, pl. 6, fig. 7.
- Globigerina subcretacea* Lomnicki, 1901, Naturf. Ver. Brunn, Verh., vol. 39, Abh., p. 17.
- Globigerinoides conglobatus* (Brady) = *Globigerina conglobata* Brady, 1879, Quart. Jour. Micr. Sci., new ser., vol. 19, p. 286.
- Globigerinoides cyclostomus* (Galloway and Wissler) = *Globigerina cyclostoma* Galloway and Wissler, 1927, Jour. Pal., vol. 1, p. 42.
- Globigerinoides minutus* Natland, 1938, California, Univ., Scripps Inst. Oceanogr., Bull., Tech. Ser., vol. 4, no. 5, p. 150, pl. 7, figs. 203. Specimens of this species have distinct secondary apertures, thus separating it from *Globigerina bradyi* Wiesner.
- Globigerinoides ruber* (d'Orbigny) = *Globigerina rubra* d'Orbigny, 1839, in de la Sagra, Hist. Phys. Pol. Nat. Cuba, "Foraminifères," pp. 82-83 (plates published separately, vol. 8, pl. 4, figs. 12-14).
- Globigerinoides sacculifer* (Brady) = *Globigerina sacculifera* Brady, 1877, Geol. Mag., n. s., dec. 2, vol. 4, no. 12, p. 535.
- Globigerinoides trilocularis* (d'Orbigny) = *Globigerina trilocularis* d'Orbigny, 1832, in Deshayes, Encyclopédie Méthodique, vol. 2, pt. 2, p. 170.
- Globorotalia menardii* (d'Orbigny) = *Rotalia menardii* d'Orbigny, 1826, Ann. Sci. Nat., Foraminifères, ser. 1, vol. 7, p. 273, Modèles, no. 10.; Parker, Jones and Brady, 1865, Ann. Mag. Nat. Hist., vol. 16, ser. 3, p. 20, pl. 3, fig. 81 (from d'Orbigny's model). There is some question as to the validity of d'Orbigny's designation; however, he issued a set of models to subscribers and it is a matter of opinion whether or not this is a published indication.

- Globorotalia puncticulata* (d'Orbigny) = *Globigerina puncticulata* d'Orbigny, 1832, in Deshayes, Encyclopédie méthodique, vol. 2, pt. 2, p. 170. According to the rules of zoological nomenclature, the first author of a species name is that person who first published the name in connection with such an indication, definition, or description provided that these indications are clearly the work of the author in question. Deshayes presented d'Orbigny's work and was clearly referring to d'Orbigny's species.
- Globorotalia tumida* (Brady) = *Pulvinulina menardii* (d'Orbigny) var. *tumida* Brady, 1877, Geol. Mag., n. s., dec. 2, vol. 4, p. 535.
- Hastigerina aequilateralis* (Brady) = *Globigerina aequilateralis* Brady, 1879, Quart. Jour. Micr. Sci., new ser., vol. 19, p. 285.
- Orbulina universa* d'Orbigny, 1839, in de la Sagra, Hist. Phys. Pol. Nat. Cuba, "Foraminifères," p. 3, pl. 1, fig. 1.
- Pulleniatina obliquiloculata* (Parker and Jones) = *Pullenia sphearoides* var. *obliquiloculata* Parker and Jones, 1865, Roy. Soc. London, Philos. Trans., vol. 155, p. 365, 368, pl. 19, fig. 4.
- BENTHONIC SPECIES
- Amphisorus hemprichii* Ehrenberg, 1840, K. Akad. Wiss. Berlin, Physik. Abh. (1838), p. 130, pl. 3, fig. 3.
- Angulogerina angulosa* (Williamson), = *Uvigerina angulosa* Williamson, 1858, Recent foramin. Gt. Britain, Ray. Soc., p. 67, pl. 5, fig. 140.
- Angulogerina carinata* Cushman, 1927, California, Univ., Scripps Inst. Oceanogr., Bull., Tech. Ser., vol. 1, p. 159, pl. 4, fig. 3.
- Archaias angulatus* (Fichtel and Moll) = *Nautilus angulatus* Fichtel and Moll, 1798, Testacea microscopica, Argonauta et Nautilus, p. 113, pl. 22, figs. a-e.
- Bolivina acuminata* Natland, = *Bolivina subadvena* Cushman var. *acuminata* Natland, 1946, in Cushman and Gray, Cushman Lab. Foramin. Res., Spec. Publ., no. 19, p. 34, pl. 5, fig. 46.
- Bolivina acutula* Bandy = *Bolivina advena* Cushman var. *acutula* Bandy, 1953, Jour. Pal., vol. 27, no. 2, p. 180, pl. 24, fig. 7.
- Bolivina albatrossi* Cushman, 1922, U.S. Nat. Mus., Bull. 104, pt. 3, p. 31, pl. 6, fig. 4.
- Bolivina argentea* Cushman, 1926, Cushman Lab. Foramin. Res., Contr., vol. 2, pt. 2, p. 42, pl. 6, fig. 5. *Bolivina subargentea* Uchio (1960) and *B. argentea* var. *monicana* Zalesny (1959) are only variations.
- Bolivina globulosa* Cushman, 1933, Cushman Lab. Foramin. Res., Contr., vol. 9, p. 80, pl. 8, fig. 9.
- Bolivina goudkoffi* Rankin, 1934, in Cushman and Kleinpell, Cushman Lab. Foramin. Res., Contr., vol. 10, p. 22, pl. 4, figs. 4-5.
- Bolivina interjuncta* Galloway and Wissler, 1927, Jour. Pal., vol. 1, p. 70, pl. 11, figs. 10-13.
- Bolivina pacifica* Cushman and McCulloch, = *Bolivina acerosa* Cushman, var. *pacifica* Cushman and McCulloch, 1942, Allan Hancock Pacific Expeditions, vol. 6, no. 4, p. 185, pl. 21, figs. 2-3.
- Bolivina plicata* d'Orbigny, 1839, Voy. Amér. Mérid., Foraminifères, vol. 5, p. 62, pl. 8, figs. 4-7.
- Bolivina pseudoplicata* Heron-Allen and Earland, 1930, Jour. Roy. Micr. Soc., vol. 50, p. 81, pl. 3, figs. 36-40.
- Bolivina quadrata* Cushman and McCulloch, 1942, Allan Hancock Pacific Expeditions, vol. 6, no. 4, p. 205, pl. 25, fig. 13.
- Bolivina seminuda* Cushman, 1911, U.S. Nat. Mus., Bull. 71, pt. 2, p. 34, text-fig. 55.
- Bolivina spissa* Cushman = *Bolivina subadvena* Cushman var. *spissa* Cushman, 1926, Cushman Lab. Foramin. Res., Contr., vol. 2, pt. 2, p. 45, pl. 6, fig. 8.
- Bolivina striatula* Cushman, 1922, Carnegie Inst. Washington, Publ. 311, p. 27, pl. 3, fig. 10.
- Bolivina tongi* Cushman, 1929, Cushman Lab. Foramin. Res., Contr., vol. 5, p. 93, pl. 13, fig. 29.
- Bolivina vaughani* Natland, 1938, California, Univ., Scripps Inst. Oceanogr., Bull., Tech. Ser., vol. 4, no. 5, p. 146, pl. 5, fig. 11.
- Bolivinita minuta* (Natland) = *Bolivina minuta* Natland, 1938, California, Univ., Scripps Inst. Oceanogr. Bull., Tech. Ser., vol. 4, p. 146, pl. 5, fig. 10.
- Buccella manskeldi* (Cushman) = *Eponides manskeldi* Cushman, 1930, Florida, Geol. Survey, Bull. 4, p. 54, pl. 11, fig. 1.
- Buccella tenerrima* (Bandy) = *Rotalia tenerrima* Bandy, 1950, Jour. Pal., vol. 24, no. 3, p. 278, pl. 42, fig. 3. *Buccella inusitata* Andersen, 1952, is considered to be a junior synonym of *B. tenerrima*.
- Bulimina affinis* d'Orbigny, 1839, in de la Sagra, Hist. Phys. Pol. Nat. Cuba, "Foraminifères," p. 105, pl. 2, figs. 25-26.
- Bulimina denudata* Cushman and Parker, 1938, Cushman Lab. Foramin. Res., Contr., vol. 14, p. 57, pl. 10, figs. 1-2.
- Bulimina marginata* d'Orbigny, 1826, Ann. Sci. Nat., Foraminifères, ser. 1, vol. 7, p. 269, no. 4, pl. 12, figs. 10-12.
- Bulimina pulchella* d'Orbigny, 1839, Voy. Amér. Mérid., Foraminifères, vol. 5, pt. 5, p. 50, pl. 1, figs. 6-7.
- Bulimina rostrata* H. B. Brady, 1884, Rept. Voy. Challenger, Zool., vol. 9, p. 408, pl. 51, figs. 14-15.
- Bulimina spinifera* Cushman, 1927, California, Univ., Scripps Inst. Oceanogr. Bull., Tech. Ser. vol. 1, p. 151, pl. 2, fig. 15.
- Bulimina striata* d'Orbigny var. *mexicana* Cushman = *Bulimina inflata* Seguenza var. *mexicana* Cushman, 1922, U.S. Nat. Mus., Bull., 104, pt. 3, p. 95, pl. 21, fig. 2.
- Bulimina subacuminata* Cushman and Stewart, 1930, San Diego Soc. Nat. Hist., Trans., vol. 6, p. 65, pl. 5, figs. 2-3.
- Buliminella curta* Cushman, 1925, Cushman Lab. Foramin. Res., Contr., vol. 1, no. 8, p. 33, pl. 5, fig. 13.
- Buliminella elegantissima* (d'Orbigny) = *Bulimina elegantissima* d'Orbigny, 1839, Voy. Amér. Mérid., Foraminifères, vol. 5, pt. 5, p. 51, pl. 7, figs. 13-14.
- Buliminella exilis* (H. B. Brady) var. *tenuata* Cushman = *Buliminella subfusiformis* Cushman var. *tenuata* Cushman, 1927, California, Univ., Scripps Inst. Oceanogr., Bull., Tech. Ser., vol. 1, p. 149, pl. 2, fig. 9.
- Cancris auricula* (Fichtel and Moll) = *Nautilus auricula* Fichtel and Moll, 1798, Testacea microscopica, 1798, p. 108, pl. 20, figs. a-c.
- Cancris panamensis* Natland, 1938, California, Univ., Scripps Inst. Oceanogr., Bull., Tech. Ser., vol. 4, no. 5, p. 148, pl. 6, fig. 1.
- Cassidulina cushmani* Stewart and Stewart, 1930, Jour. Pal., vol. 4, p. 71, pl. 9, fig. 5.
- Cassidulina delicata* Cushman, 1927, California, Univ., Scripps Inst. Oceanogr. Bull., Tech. Ser., vol. 1, p. 168, pl. 6, fig. 5.
- Cassidulina laevigata* d'Orbigny, 1826, Ann. Sci. Nat., ser. 1, vol. 7, p. 282, no. 1, pl. 15, figs. 4-5.
- Cassidulina limbata* Cushman and Hughes, 1925, Cushman Lab. Foramin. Res., Contr., vol. 1, no. 5, p. 12, pl. 2, fig. 2.

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- Cassidulina minuta* Cushman, 1933, Cushman Lab. Foram. Res., Contr., col. 9, pt. 4, p. 92, pl. 10, fig. 3.
- Cassidulina pulchella* d'Orbigny, 1839, Voy. Amér. Mérid., Foraminifères, vol. 5, pt. 5, p. 57, pl. 8, figs. 1-3.
- Cassidulina quadrata* Cushman and Hughes = *Cassidulina subglobosa* Brady, var. *quadrata* Cushman and Hughes, 1925, Cushman Lab. Foram. Res., Contr., vol. 1, no. 5, p. 15, pl. 2, fig. 7.
- Cassidulina subcalifornica* Drooger = *Cassidulina subglobosa* Brady var. *subcalifornica* Drooger, 1953, Cushman Found. Foram. Res., Contr., vol. 4, pt. 4, p. 140, pl. 22, figs. 8-9.
- Cassidulina subglobosa* Brady, 1881, Quart. Jour. Micr. Sci., new ser., vol. 21, p. 60.
- Cassidulina tortuosa* Cushman and Hughes, 1925, Cushman Lab. Foram. Res., Contr., vol. 1, no. 5, p. 14, pl. 2 fig. 4.
- Cassidulina translucens* Cushman and Hughes, 1925, Cushman Lab. Foram. Res., Contr. vol. 1, no. 5, p. 15, pl. 2, fig. 5.
- Cassidulinoides cornuta* (Cushman) = *Virgulina cornuta* Cushman, 1913, U.S. Nat. Mus., Proc., vol. 44, p. 637, pl. 80, fig. 1.
- Cassidulinoides tenuis* Phleger and Parker, 1951, Geol. Soc. Amer., Mem., no. 46, pt. 2, p. 27, pl. 14, figs. 14-17.
- Chilostomella ovoidea* Reuss, 1850, K. Akad. Wiss. Wien, Denkschr., vol. 1, p. 380, pl. 48, fig. 12.
- Cibicides fletcheri* Galloway and Wissler, 1927, Jour. Pal., vol. 1, no. 1, p. 64, pl. 10, figs. 8-9. This species becomes abnormal in lagoons and in some areas on the continental shelf. It occurs in all stages from typical populations to that in which later biserial chambers are added. *Dyocibicides* is a generic name commonly applied to the abnormal stage. A similar sequence of abnormality is introduced in other rotaloids such as *Rotalina versiformis* (Bandy) and *Cibicides lobatus* (Montagu). *Cibicides conoideus* Galloway and Wissler, 1927, is considered to be a variant of *C. fletcheri*.
- Cibicides lobatus* (Montagu) = *Serpula lobata* Montagu, 1803, Test. Brit., pp. 515, 516.
- Cibicides mckannai* Galloway and Wissler, 1927, Jour. Pal., vol. 1, p. 65, pl. 10, fig. 5.
- Cibicides spiralis* Natland, 1938, California, Univ., Scripps Inst. Oceanogr., Bull., Tech. Ser. vol. 4, no. 5, p. 151, pl. 7, fig. 7.
- Cibicides wuellerstorfi* (Schwager) = *Anomalina wuellerstorfi* Schwager, 1866, Novara-Exped., Geol. Theil., vol. 2, p. 258, pl. 7, figs. 105, 107.
- Eggerella advena* (Cushman) = *Verneuilina advena* Cushman, 1922, Contr. Canadian Biol., no. 9, p. 141.
- Ehrenbergina compressa* Cushman, 1927, California, Univ., Scripps Inst. Oceanogr., Bull., Tech. Ser., vol. 1, p. 168, pl. 6, fig. 7.
- Elphidium articulatum* (d'Orbigny) = *Polystomella articulata* d'Orbigny, 1839, Voy. Amér. Mérid., Foraminifères, vol. 5, pt. 5, p. 30, pl. 3, figs. 9-10.
- Elphidium articulatum* (d'Orbigny) var. *rugulosum* Cushman and Wickenden, 1929, U.S. Nat. Mus., Proc. 2780, vol. 75, art. 9, p. 7, pl. 3, fig. 8.
- Elphidium crispum* (Linné) = *Nautilus crispus* Linné, 1758, Systema naturae, ed. 10, p. 709.
- Elphidium discoidale* (d'Orbigny) = *Polystomella discoidalis* d'Orbigny, 1839, in de la Sagra, Hist. Phys. Pol. Nat. Cuba, "Foraminifères," p. 56, pl. 6, figs. 23-24.
- Elphidium mexicanum* Kornfeld = *Elphidium incertum* (Williamson) var. *mexicanum* Kornfeld, 1931, Stanford Univ., Geology Dept., Contr., vol. 1, no. 3, p. 89, pl. 16, fig. 1-2.
- Elphidium poeyanum* (d'Orbigny) = *Polystomella poeyana* d'Orbigny, 1839, in de la Sagra, Hist. Phys. Pol. Nat. Cuba, "Foraminifères," p. 55, pl. 6, figs. 25-26.
- Elphidium translucens* Natland, 1938, California, Univ., Scripps Inst. Oceanogr., Bull., Tech. Ser., vol. 4, no. 5, p. 144, pl. 5, figs. 5-6.
- Epistominella bradyana* (Cushman) = *Pulvinulinella bradyana* Cushman, 1927, California, Univ., Scripps Inst. Oceanogr., Bull., Tech. Ser., vol. 1, p. 165, pl. 5, figs. 11-13.
- Epistominella exigua* (Brady) = *Pulvinulina exigua* Brady, 1884, Rept. Voy. Challenger, Zool., vol. 9, p. 696, pl. 103, figs. 13-14. *Epistominella sandiegoensis* Uchio (1960) is considered to be synonymous with the earlier form, *E. exigua*.
- Epistominella levicula* Resig, 1958, Micropaleontology, vol. 4, no. 3, p. 304, text-fig. 16.
- Epistominella obesa* Bandy and Arnal, 1957, Cushman Found. Foram. Res., Contr., vol. 8, pt. 2, p. 56, pl. 7, fig. 8.
- Epistominella smithi* (Stewart and Stewart) = *Pulvinulinella smithi* Stewart and Stewart, 1930, Jour. Pal., vol. 4, p. 70, pl. 9, fig. 4.
- Eponides antillarum* (d'Orbigny) = *Rotalina antillarum* d'Orbigny, 1839, in de la Sagra, Hist. Phys. Pol. Nat. Cuba, "Foraminifères," p. 75.
- Eponides ecuadorensis* (Galloway and Morrey) = *Rotalia ecuadorensis* Galloway and Morrey, 1929, Bull. Amer. Pal., vol. 15, no. 55, p. 26, pl. 3, fig. 13.
- Eponides pseudoaffinis* Bandy and Arnal, 1957, Cushman Lab. Foram. Res., Contr., vol. 8, pt. 2, p. 57, pl. 7, fig. 9.
- Eponides repandus* (Fichtel and Moll) = *Nautilus repandus* Fichtel and Moll, 1798, Testacea microscopica, p. 35, pl. 3, figs. a-d. A study of this form by J. Resig shows that *Poroepionides cribrorrepandus* is simply a variant. The two should be placed in the same species.
- Eponides tumidulus* (Brady) = *Truncatulina tumidula* Brady, 1884, Rept. Voy. Challenger, Zool., pt. 22, vol. 9, p. 666, pl. 95, fig. 8.
- Gaudryina arenaria* Galloway and Wissler, 1927, Jour. Pal., vol. 1, p. 68, pl. 11, fig. 5.
- Gaudryina atlantica* (Bailey) = *Textularia atlantica* Bailey, 1851, Smithsonian Inst., Contr. Knowledge, vol. 2, art. 3, p. 12, pl. figs. 38-43.
- Gaudryina subglabrata* Cushman and McCulloch, 1939, Allan Hancock Pacific Exped., vol. 6, no. 1, p. 92, pl. 8, figs. 5-7.
- Glabratella lauriei* (Heron-Allen and Earland) = *Discorbina lauriei* Heron-Allen and Earland, 1924, Linn. Soc. London, Jour., Zool., vol. 35, p. 633, pl. 36, figs. 50-52.
- Globobulimina pacifica* Cushman, 1927, Cushman Lab. Foram. Res., Contr., vol. 3, p. 67, pl. 14, fig. 12.
- Gyroidina altiformis* Stewart and Stewart = *Gyroidina soldanii* d'Orbigny var. *altiformis* Stewart and Stewart, 1930, Jour. Pal., vol. 4, p. 67, pl. 9, fig. 2.
- Gyroidina gemma* Bandy, 1953, Jour. Pal., vol. 27, no. 2, p. 179, pl. 23, fig. 4.
- Gyroidina multilocula* Coryell and Mossman = *Gyroidina soldanii* d'Orbigny var. *multilocula* Coryell and Mossman, 1942, Jour. Pal., vol. 16, p. 237, pl. 36, fig. 20.
- Gyroidina orbicularis* d'Orbigny, 1826, Ann. Sci. Nat., Foraminifères, ser. 1, vol. 7, p. 278, Modèles, no. 13. This species may vary from a condition with no umbilicus to forms with a slight umbilicus.

- Gyroidina rothwelli* Natland, 1950, Geol. Soc. Amer., Mem., no. 43, pt. 4, p. 29, pl. 7, fig. 8.
- Gyroidina soldanii* d'Orbigny, 1826, Ann. Sci. Nat., ser. 1, vol. 7, p. 278; Modèles, no. 36.
- Hanzawaia bertheloti* (d'Orbigny) = *Rosalina bertheloti* d'Orbigny, 1839, in Barker-Weeb and Berthelot, Hist. Nat. Îles Canaries, "Foraminifères," vol. 2, pt. 2, p. 135, pl. 1, figs. 28-30.
- Hanzawaia nitidula* (Bandy) = *Cibicidina basiloba* (Cushman) var. *nitidula* Bandy, 1953, Jour. Pal., vol. 27, no. 2, p. 178, pl. 22, fig. 3.
- Hauerina bradyi* Cushman, 1917, U.S. Nat. Mus., Bull., no. 71, p. 62, pl. 23, fig. 2.
- Laticarinina pauperata* (Parker and Jones) = *Pulvinulina repanda* (Fichtel and Moll) var. *menardii* (d'Orbigny) subvar. *pauperata* Parker and Jones, 1865, Roy. Soc. London, Philos. Trans., vol. 155, p. 395, pl. 16, figs. 50-51.
- Loxostomum limbatum* (Brady) = *Bolivina limbata* Brady, 1881, Quart. Jour. Micr. Sci., vol. 21, p. 27.
- Loxostomum mayori* (Cushman) = *Bolivina mayori* Cushman, 1922, Carnegie Instit. Washington, Publ. 311, p. 27, pl. 3, figs. 5-6.
- Loxostomum pseudobeyrichi* (Cushman) = *Bolivina pseudobeyrichi* Cushman, 1926, Cushman Lab. Foram. Res., Contr., vol. 2, pt. 2, p. 45.
- Martinottiella occidentalis* (Cushman) = *Clavulina occidentalis* Cushman 1922, U.S. Nat. Mus., Bull. 104, pt. 3, p. 87, pl. 17, figs. 1-2.
- Martinottiella pallida* (Cushman) = *Clavulina communis* d'Orbigny var. *pallida* Cushman, 1927, California, Univ., Scripps Instit. Oceanogr. Bull., Tech. Ser., vol. 1, no. 10, p. 138, pl. 2, fig. 1.
- Nodobacularella atlantica* Cushman and Hanzawa, 1937, Cushman Lab. Foram. Res., Contr., vol. 13, pt. 2, p. 42, pl. 5, figs. 7-8.
- Nonion barleanus* (Williamson) = *Nonionina barleana* Williamson, 1858, Recent foram. Gt. Britain, Ray Soc., p. 32, pl. 3, figs. 68-69. *Nonion parkerae* Uchio (1960) is considered to be a junior synonym of this species.
- Nonion pompilioides* (Fichtel and Moll) = *Nautilus pompilioides* Fichtel and Moll, 1798, Testacea microscopia, p. 31, pl. 2, figs. a-c.
- Nonionella atlantica* Cushman, 1947, Cushman Lab. Foram. Res., Contr., vol. 23, pt. 4, p. 90, pl. 20, figs. 4-5.
- Nonionella basispinata* (Cushman and Moyer) = *Nonion pizarrensis* Berry var. *basispinata* Cushman and Moyer, 1930, Cushman Lab. Foram. Res., Contr., vol. 6, p. 54, pl. 7, fig. 18.
- Nonionella chilensis* Cushman and Kellett, 1929, U.S. Nat. Mus., Proc., no. 2796, v. 75, art. 25, p. 6, pl. 2, fig. 4.
- Nonionella decora* Cushman and McCulloch, 1940, Allan Hancock Pacific Exped., vol. 6, no. 3, p. 160, pl. 17, figs. 11-12.
- Nonionella grateloupi* (d'Orbigny) = *Nonionina grateloupi* d'Orbigny, 1839, in de la Sagra, Hist. Phys. Pol. Nat. Cuba, "Foraminifères," p. 46, pl. 6, figs. 6-7.
- Nonionella miocenica* Cushman var. *stella* Cushman and Moyer, 1930, Cushman Lab. Foram. Res., Contr., vol. 6, p. 56, pl. 7, fig. 17.
- Osangularia bengalensis* (Schwager) = *Anomalina bengalensis* Schwager, 1866, Novara-Exped., Geol. Theil, vol. 2, pt. 2, p. 259, pl. 7, fig. 111.
- Patellina corrugata* Williamson, 1858, Recent foram. Gt. Britain, Ray. Soc., London, p. 46, pl. 3, figs. 86-89.
- Peneroplis pertusus* (Forsk.) = *Nautilus pertusus* Forskal, 1775, Descriptiones animalium, p. 125.
- Planispirina exigua* (Brady) = *Hauerina exigua* Brady, 1879, Quart. Jour. Micr. Sci., London, n. s., vol. 19, p. 267.
- Planorbulina mediterraneensis* d'Orbigny, 1826, Ann. Sci. Nat. Foraminifères Ser. 1, vol. 7, p. 280, no. 2, pl. 14, figs. 4-6.
- Planulina ariminensis* d'Orbigny, 1826, Ann. Sci. Nat., Foraminifères, ser. 1, vol. 7, p. 280, pl. 14, figs. 1-3.
- Planulina ornata* (d'Orbigny) = *Truncalina ornata* d'Orbigny, 1839, Voy. Amér. Mérid., Foraminifères, vol. 5, pt. 5, p. 40, pl. 6, figs. 7-9.
- Pseudopionides tener* (Brady) = *Truncatolina tenera* Brady, 1884, Rept. Voy. Challenger, Zool., vol. 9, p. 665, pl. 95, fig. 11.
- Pullenia bulloides* (d'Orbigny) = *Nonionina bulloides* d'Orbigny, 1826, Ann. Sci. Nat., Foraminifères, ser. 1, vol. 7, p. 293.
- Pullenia malkinae* Coryell and Mossman, 1942, Jour. Pal., vol. 16, p. 234, pl. 36, figs. 3-4.
- Pullenia salisburyi* Stewart and Stewart, 1930, Jour. Pal., vol. 4, no. 1, p. 72, pl. 8, fig. 2.
- Pyrgo murrhina* (Schwager) = *Biloculina murrhina* Schwager, 1866, Novara-Exped., Geol. Theil, vol. 2, p. 203, pl. 4, fig. 15.
- Quinqueloculina akneriana* d'Orbigny var. *bellatula* Bandy, 1950, Jour. Pal., vol. 24, no. 3, p. 273, pl. 41, fig. 1.
- Quinqueloculina angularis* d'Orbigny, 1905, in Fornasini, R. Accad. Sci. Inst. Bologna, Mem. Sci. Nat., ser. 6, vol. 2, p. 66, pl. 3, fig. 12.
- Quinqueloculina angulostriata* Cushman and Valentine, 1930, Stanford Univ., Dept. Geol., Contr., vol. 1, no. 1, p. 12, pl. 2, fig. 5.
- Quinqueloculina boschiana* d'Orbigny, 1839, in de la Sagra, Hist. Phys. Pol. Nat. Cuba, "Foraminifères," p. 191, pl. 11, figs. 22-24.
- Quinqueloculina catalinensis* Natland, 1938, California, Univ., Scripps Inst. Oceanogr., Bull., Tech. Ser., vol. 4, no. 5, p. 142, pl. 4, fig. 3.
- Quinqueloculina* sp. cf. *Quinqueloculina crassiformis* Cushman and Ellisor, 1945, Jour. Pal., vol. 19, p. 549, pl. 72, fig. 3.
- Quinqueloculina lamarckiana* d'Orbigny, 1839, in de la Sagra, Hist. Phys. Pol. Nat. Cuba, "Foraminifères," p. 189, pl. 11, figs. 14-15.
- Quinqueloculina poeyana* d'Orbigny, 1839, in de la Sagra, Hist. Phys. Pol. Nat. Cuba, "Foraminifères," p. 191, pl. 11, figs. 25-27.
- Quinqueloculina rhodiensis* Parker, 1953, Cushman Found. Foram. Res., Spec. Publ., no. 2, p. 12, pl. 2, figs. 15-17.
- Rectobolivina hancocki* (Cushman and McCulloch) = *Bifarina hancocki* Cushman and McCulloch, 1942, Allan Hancock Pacific Exped., vol. 6, no. 4, p. 225, pl. 28, figs. 13-19.
- Reussella aequa* Cushman and McCulloch, 1948, Allan Hancock Pacific Exped. vol. 6, no. 5, p. 251, pl. 31, fig. 7.
- Reussella pacifica* Cushman and McCulloch, 1948, Allan Hancock Pacific Exped., vol. 6, no. 5, pl. 31, fig. 6.
- Rosalina concinna* (Brady) = *Discorbina concinna* Brady, 1884, Rept. Voy. Challenger, Zool., pt. 22, vol. 9, p. 646, pl. 90, figs. 7-8.
- Rotorbinella lomaensis* (Bandy) = *Rotalia lomaensis* Bandy, 1953, Jour. Pal., vol. 27, no. 2, p. 179, pl. 22, fig. 6.

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- Rotorbinella rosea* (d'Orbigny) = *Rotalia rosea* d'Orbigny, 1826, Ann. Sci. Nat. Foraminifères, ser. I, vol. 7, p. 272; Modèles, no. 35.
- Rotorbinella turbinata* (Cushman and Valentine) = *Rotalia turbinata* Cushman and Valentine, 1930, Stanford Univ., Dept. Geol., Contr., vol. 1, no. 1, p. 25, pl. 7, figs. 1, 3.
- Rotorbinella versiformis* (Bandy) = *Rotalia versiformis* Bandy, 1953, Jour. Pal., vol. 27, no. 2, p. 179, pl. 22, fig. 5.
- Sigmoilina tenuis* (Czjzek) = *Quinqueloculina tenuis* Czjzek, 1848, Haidinger's Naturw. Abh., vol. 2, p. 149, pl. 13, figs. 31-34.
- Spiroloculina antillarum* d'Orbigny, 1839, in de la Sagra, Hist. Phys. Pol. Nat. Cuba, "Foraminifères," p. 166, vol. 8, pl. 9, figs. 3-4.
- Spiroloculina communis* Cushman and Todd, 1944, Cushman Lab. Foram. Res., Spec. Publ., no. 11, p. 63, pl. 9, figs. 4-5.
- Streblus tepidus* (Cushman) = *Rotalia beccarii* (Linnaé) var. *tepidus* Cushman, 1926, Carnegie Inst. Washington, Publ. no. 344, p. 79, pl. 1.
- Suggrunda eckisi* Natland, 1950, Geol. Soc. Amer., Mem., no. 43, pt. 4, p. 23, pl. 9, fig. 12.
- Textularia conica* d'Orbigny, 1839, in de la Sagra, Hist. Phys. Pol. Nat. Cuba, "Foraminifères," p. 143, vol. 8, pl. 1, figs. 19-20.
- Textularia foliacea* Heron-Allen and Earland, 1915, Zool. Soc. London, Trans., vol. 20, pt. 17, p. 628, pl. 47, figs. 17-20.
- Textularia schencki* Cushman and Valentine, 1930, Stanford Univ., Dept. Geol., Contr., vol. 1, no. 1, p. 8, pl. 1, fig. 3.
- Textularia secasensis* Lalicker and McCulloch, 1940, Allan Hancock Pacific Exped., vol. 6, no. 2, p. 141, pl. 16, fig. 24.
- Tretomphalus myersi* Cushman, 1943, Cushman Lab. Foram. Res. Contr., vol. 19, p. 26, pl. 6, figs. 4-6.
- Triloculina trigonula* (Lamarck) = *Miliolites trigonula* Lamarck, 1804, Paris, Mus. Nat. Hist., Ann., vol. 5, p. 351; 1807, idem, vol. 9, pl. 17, fig. 4.
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- Virgulina nodosa* Stewart and Stewart, 1930, Jour. Pal., vol. 4, no. 1, p. 64, pl. 8, fig. 4.
- Virgulina schreibersiana* Czjzek, 1848, Haidinger's Naturw. Abh., vol. 2, p. 11, pl. 13, figs. 18-21.
- Virgulina seminuda* Natland, 1938, California, Univ., Scripps Inst. Oceanogr., Bull., Tech. Ser., vol. 4, p. 145, pl. 5, fig. 12.
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APPENDIX B - SAMPLES, LOCATIONS, AND DEPTHS

Station number	Latitude North	Longitude West	Depth in fathoms
Allan Hancock Foundation samples			
1727-49	22°54'23"	109°50'09"	0
1730-49	23°00'30"	109°42'55"	0
1766-49	27°56'52"	111°05'11"	0
1778-49	24°25'32"	110°21'31"	6
1723-49	22°53'16"	109°52'16"	10
1777-49	24°25'27"	110°21'49"	18
1725-49	22°52'53"	109°51'11"	20
1726-49	22°52'47"	109°50'59"	30
1732-49	25°24'45"	109°23'50"	50
1776-49	24°25'25"	110°22'40"	51
1729-49	23°01'14"	109°28'45"	70
1760-49	27°05'30"	110°57'40"	920

Scripps cores collected in 1939

3	22°56.0'	109°11.0'	1577
4	23°01.6'	108°36.8'	1449
5	22°58.0'	108°14.5'	1581
6	23°01.0'	107°48.2'	1339
8	23°10.0'	107°04.5'	605
10	23°09.7'	106°37.0'	54
11	24°46.5'	108°24.2'	254
12	24°37.8'	108°33.0'	648
15	24°20.0'	109°10.8'	1695
16	24°14.5'	109°24.2'	963
18	25°14.0'	110°38.6'	533
19	25°18.0'	110°27.0'	829
21	25°22.5'	109°57.0'	1640
23	25°33.8'	109°27.6'	530

BANDY

Station number	Latitude North	Longitude West	Depth in fathoms	Station number	Latitude North	Longitude West	Depth in fathoms
24	26°37.8'	110°00.8'	241	16-114	25°58.7'	111°16.9'	205
25	26°35.0'	110°15.0'	541	16-115	25°53.1'	111°17.4'	141
26	26°28.0'	110°29.0'	682	16-142	27°18.0'	111°28.2'	1120
29	26°09.5'	111°13.2'	228	16-144	27°08.6'	111°40.0'	935
30	27°14.0'	111°10.0'	951	16-152	26°35.1'	111°46.2'	17
31	27°46.0'	110°56.0'	137	16-176	27°06.0'	112°00.3'	14
32	27°38.7'	111°03.0'	364	16-180	28°45'	112°22.4'	10
35	27°01.6'	111°47.1'	456	16-181	28°45.8'	112°25.7'	116
36	27°40.0'	112°19.0'	445	16-183	28°42.5'	112°28.5'	458
38	28°07.0'	112°10.5'	470	16-184	28°41'	112°30'	183
39	28°17.0'	112°06.0'	172	16-185	28°36'	112°30.3'	165
41	29°05.8'	112°38.3'	119	16-199	28°44.3'	112°34.6'	41
44	30°18.0'	113°13.0'	67	16-205	28°46.9'	112°25.7'	10
45	30°09.7'	113°32.0'	91	16-220	28°28.3'	112°53.3'	105
46	29°55.2'	113°54.2'	268	Scripps snapper samples collected in 1940			
47	29°56.0'	114°11.0'	195	16-60	27°17.5'	110°54'	445
48	30°42.0'	114°22.0'	45	16-63	27°57'	111°03.5'	5
50	31°03.0'	113°40.0'	30	16-68	25°51.8'	111°11.3'	32
51	31°14.0'	114°14.0'	28	16-77	26°00.6'	111°04.1'	174
51B	31°04.0'	114°22.0'	44	16-80	25°51.4'	111°19.2'	31
53	28°46.5'	113°08.2'	716	16-82	25°57.3'	111°18.9'	117
Scripps cores collected in 1940				16-83	25°58.7'	111°19.2'	73
16-7	27°48.6'	110°47.5'	23	16-84	26°01.8'	111°19.1'	35
16-8	27°43.0'	110°50.2'	111	16-85	26°04.6'	111°18.4'	37
16-10	27°17.2'	111°07.9'	955	16-88	26°04.4'	111°13.1'	115
16-11	27°52.6'	111°03.0'	47	16-89	26°02.1'	111°13.9'	205
16-12	27°50.4'	111°05.2'	154	16-90	26°00.6'	111°16.2'	215
16-13	27°48.3'	111°07.9'	219	16-96	26°05.9'	111°17.6'	6
16-14	27°45.1'	111°11.5'	226	16-97	26°05.7'	111°17.8'	12
16-15	27°40.9'	111°16.2'	410	16-98	26°05.4'	111°18'	26
16-16	27°37.4'	111°19.2'	515	16-99	26°05.2'	111°18.1'	39
16-17	27°46.8'	110°50'	27	16-112	25°47.7'	111°12.9'	13
16-18	27°42.2'	110°53.8'	253	16-117	25°36.8'	111°03'	131
16-19	27°41.0'	110°55.5'	333	16-146	26°51.8'	111°53.3'	12 1/2
16-20	27°37.7'	111°00.9'	508	16-147	26°49.6'	111°52.5'	7
16-21	27°34.7'	111°05.0'	610	16-149	26°45.1'	111°51.5'	12
16-22	27°31'	111°10'	830	16-153	26°45.7'	111°52.3'	7 1/2
16-25	27°31.5'	110°56.6'	750	16-154	26°57'	111°55.3'	34
16-28	27°40.4'	110°46.0'	46	16-156	27°05.9'	111°55.7'	51
16-29	27°44.8'	110°51.3'	80	16-157	27°08.1'	112°00.8'	37
16-32	27°50.7'	110°45.2'	12	16-158	27°10.3'	112°05.'	3
16-33	27°48.1'	110°47.1'		16-159	27°10.1'	112°04.9'	6
16-35	27°44.1'	110°42.2'	20	16-161	27°10.6'	112°02.8'	13 1/2
16-37	27°39.4'	110°46.7'	55	16-171	27°08.5'	111°49.3'	680
16-39	27°57.7'	111°12.9'	44	16-172	27°11.3'	111°45.3'	765
16-40	27°56.6'	111°14.5'	125	16-173	27°14.7'	111°40.7'	940
16-41	27°54.7'	111°18.8'	168	16-174	27°18.9'	111°36.3'	1020
16-45	28°05.6'	111°24.6'	122	16-175	27°16.3'	111°32.2'	1000
16-46	28°03.0'	111°27.4'	184	16-177	27°16.3'	111°51.7'	818
16-47	27°59.8'	111°31.4'	263	16-185a	28°26'	112°30.3'	165
16-48	27°56.0'	111°36.8'	353	16-186	28°30'	112°30.4'	283
16-49	27°53.6'	111°41.5'	385	16-190	28°15.7'	112°30.3'	340
16-52	27°51.5'	111°25.2'	320	16-191	28°15.6'	112°21.9'	463
16-56	27°27'	110°42.9'	22	16-192	28°20.5'	112°19.0'	385
16-61	27°14.4'	110°59.2'	853	16-194	28°29.0'	112°19.7'	117
16-70	25°51.8'	111°08.9'	148	16-195	28°35.5'	112°20.9'	103
16-71	25°51.8'	110°59.9'	316	16-201	28°46.3'	112°44.3'	225
16-73	25°52.3'	110°39.8'	640	16-202	28°46.8'	112°51.3'	225
16-74	25°52'	110°21.8'	850	16-203	28°54.0'	112°44.5'	290
16-75	25°59.5'	110°27.9'	750	16-204	28°51.2'	112°37.8'	289
16-76	25°59.8'	110°37.9'	740	16-212	29°10.3'	112°55.4'	225
16-109	26°16.5'	110°48.8'	985	16-218	29°05.8'	113°21.2'	600
16-111	26°08.8'	110°30.0'	1277	16-221	28°43.0'	113°03.8'	810

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PLATE 1

EURYHALINE FAUNA - SELECTED REPRESENTATIVES

- 1 *Quinqueloculina akneriana* d'Orbigny var. *bellatula* Bandy
a, side view; b, opposite side, $\times 85$.
- 2 *Quinqueloculina angulosa* d'Orbigny
a, side view; b, opposite side; $\times 52$.
- 3 *Quinqueloculina rhodiensis* Parker
a, side view; b, opposite side; $\times 68$.
- 4 *Elphidium articulatum* (d'Orbigny) var. *rugulosum* Cushman and Wickenden.
Side view; $\times 122$.
- 5 *Streblus tepidus* (Cushman)
a, ventral view; b, edge view; c, dorsal view; $\times 150$.

BEACH FAUNA - SELECTED REPRESENTATIVES

- 6 *Bolivina vughani* Natland
Side view; $\times 167$.
- 7 *Buccella tenerrima* (Bandy)
a, ventral view; b, edge view; c, dorsal view; $\times 113$.
- 8 *Elphidium crispum* (Linne)
Side view; $\times 15$.
- 9 *Quinqueloculina* sp. cf. *Quinqueloculina crassiformis* Cushman and Ellisor
a, side view; b, opposite side; c, apertural view; $\times 47$.
- 10 *Quinqueloculina lamarkiana* d'Orbigny
a, side view; b, opposite side; $\times 64$.

INNER SHELF BIOFACIES - SELECTED REPRESENTATIVES FAUNA I

- 11 *Textularia schencki* Cushman and Valentine
a, side view; b, apertural view; $\times 71$.

PLATE 2

INNER SHELF BIOFACIES - SELECTED REPRESENTATIVES FAUNA I

- 1 *Buccella mansfieldi* (Cushman)
a, ventral view; b, edge view; $\times 104$.
- 2 *Hanzawaia nitidula* (Bandy)
a, dorsal view; b, edge view; c, ventral view; $\times 104$.
- 3 *Buccella tenerrima* (Bandy) var.
a, ventral view; b, edge view; c, dorsal view; $\times 135$.
- 4 *Quinqueloculina poeyana* d'Orbigny
a, side view; b, apertural view; c, opposite side; $\times 60$.
- 5 *Elphidium poeyanum* (d'Orbigny)
Side view; $\times 125$.
- 6 *Elphidium translucens* Natland
Side view; $\times 125$.

FAUNA 2

- 7 *Bulimina marginata* d'Orbigny var.
Side view; $\times 115$.
- 8 *Buliminella elegantissima* (d'Orbigny)
Side view; $\times 188$.
- 9 *Gypsina vesicularis* (Parker and Jones)
 $\times 67$.
- 10 *Nonionella basispinata* (Cushman and Moyer)
a, side view; b, edge view; c, opposite side; $\times 80$.
- 11 *Nonionella atlantica* Cushman
a, side view; b, edge view; c, opposite side; $\times 135$.
- 12 *Quinqueloculina catalinensis* Natland
a, side view; b, apertural view; c, opposite side; $\times 47$.

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PLATE 3

OUTER SHELF BIOFACIES - SELECTED REPRESENTATIVES

- 1 *Bolivina acutula* Bandy
Side view; $\times 113$.
- 2 *Bulimina denudata* Cushman and Parker
Side view; $\times 96$.
- 3 *Bulimina marginata* d'Orbigny var.
Side view; $\times 90$.
- 4 *Cassidulina minuta* Cushman
a, side view; b, opposite side; $\times 225$.
- 5 *Planulina ornata* (d'Orbigny)
a, ventral view; b, edge view; c, dorsal view; $\times 75$.
- 6 *Cancris auricula* (Fichtel and Moll)
a, ventral view; b, edge view; c, dorsal view; $\times 80$.

INNER SHELF BIOFACIES - SELECTED REPRESENTATIVES

- 7 *Loxostomum mayori* (Cushman)
Side view; $\times 71$.
- 8 *Rectobolivina hancocki* (Cushman and McCulloch)
Side view; $\times 75$.
- 9 *Virgulina schreibersiana* Czjzek
Side view; $\times 96$.

OUTER SHELF BIOFACIES - SELECTED REPRESENTATIVES

- 10 *Hanzawaia bertheloti* (d'Orbigny)
a, ventral view; b, edge view; c, dorsal view; $\times 68$.
- 11 *Bolivina acuminata* Natland
Side view; $\times 104$.
- 12 *Bolivina interjuncta* Galloway and Wissler
Side view; $\times 45$.
- 13 *Uvigerina incilis* Todd
Side view; $\times 60$.
- 14 *Cibicides mckannai* Galloway and Wissler
a, ventral view; b, edge view; c, dorsal view; $\times 68$.
- 15 *Cancris panamensis* Natland
a, ventral view; b, edge view; c, dorsal view; $\times 79$.
- 16 *Epistominella bradyana* (Cushman)
a, dorsal view; b, ventral view; $\times 225$.

PLATE 4

UPPER BATHYAL BIOFACIES - SELECTED REPRESENTATIVES

- 1 *Valvulineria inflata* (d'Orbigny)
a, ventral view; b, edge view; c, dorsal view; $\times 49$.
- 2 *Bolivina plicata* d'Orbigny
Side view; $\times 60$.
- 3 *Uvigerina peregrina* Cushman
Side view; $\times 49$.
- 4 *Uvigerina excellens* Todd
Side view; $\times 71$.
- 5 *Valvulineria inaequalis* (d'Orbigny)
a, ventral view; b, edge view; c, dorsal view; $\times 41$.
- 6 *Cassidulina subcalifornica* Drooger
a, side view; b, opposite side; $\times 64$.

- 7 *Cassidulinoides tenuis* Phleger and Parker
Edge view; $\times 96$.
- 8 *Bolivina seminuda* Cushman
Side view; $\times 50$.
- 9 *Bolivina spissa* Cushman
Side view; $\times 43$.
- 10 *Buliminella exilis* (Brady) var. *tenuata* Cushman
Side view; $\times 50$.
- 11 *Loxostomum pseudobeyrichi* (Cushman)
Side view; $\times 45$.
- 12 *Cassidulinoides cornuta* (Cushman)
a, side view; b, edge view; $\times 85$.
- 13 *Cassidulina delicata* Cushman
a, side view; b, opposite side; $\times 122$.

PLATE 5

UPPER MIDDLE BATHYAL BIOFACIES - SELECTED REPRESENTATIVES

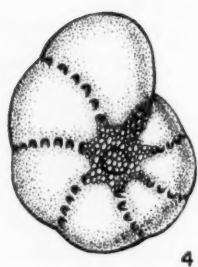
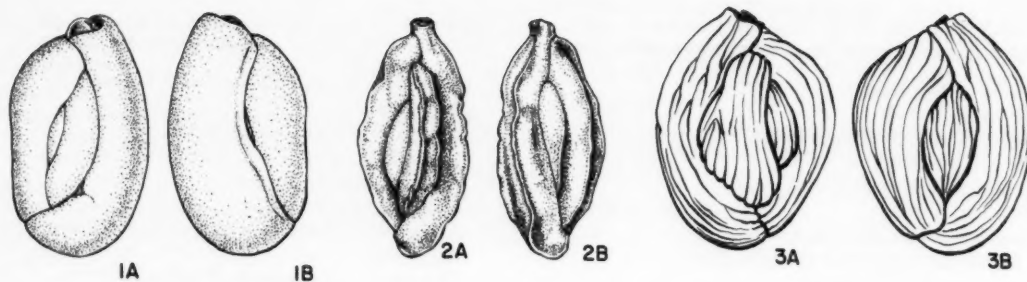
- 1 *Bolivina argentea* Cushman
Side view; $\times 59$.
- 2 *Bulimina striata* d'Orbigny var. *mexicana* Cushman
Side view; $\times 79$.
- 3 *Bulimina* sp.
Side view; $\times 43$.
- 4 *Bulimina affinis* d'Orbigny
Side view; $\times 50$.
- 5 *Pyrgo murrhina* (Schwager)
Side view; $\times 43$.
- 6 *Epistominella smithi* (R. E. and K. C. Stewart)
a, ventral view; b, edge view; c, dorsal view; $\times 150$.

LOWER MIDDLE BATHYAL BIOFACIES - SELECTED REPRESENTATIVES

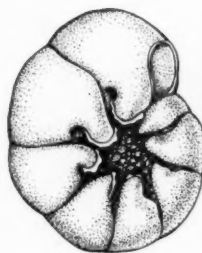
- 7 *Uvigerina hispida* Schwager
Side view; $\times 49$.
- 8 *Uvigerina peregrina* Cushman var. *disrupta* Todd
Side view; $\times 43$.
- 9 *Nonion barleanus* (Williamson)
a, side view; b, edge view; $\times 79$.
- 10 *Virgulina spinosa* Heron-Allen and Earland
Side view; $\times 135$.

POWER BATHYAL BIOFACIES - SELECTED REPRESENTATIVES

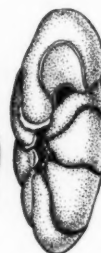
- 11 *Gyroidina soldanii* d'Orbigny
a, ventral view; b, edge view; c, dorsal view; $\times 47$.
- 12 *Nonion pompilioides* (Fichtel and Moll)
a, side view; b, edge view; $\times 104$.
- 13 *Pullenia bulloides* (d'Orbigny)
a, side view; b, edge view; $\times 150$.
- 14 *Uvigerina senticosa* Cushman
Side view; $\times 57$.
- 15 *Bulimina rostrata* Brady
Side view; $\times 113$.



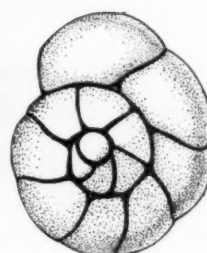
4



5A



5B

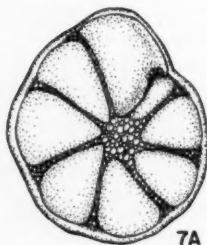


5C

EURYHALINE FAUNA



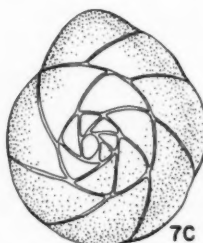
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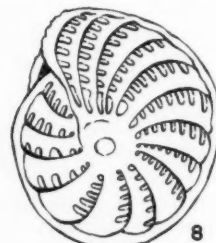
7A



7B



7C



8



9C



9B



9A

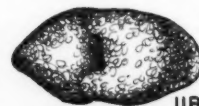


10A



10B

BEACH FAUNA

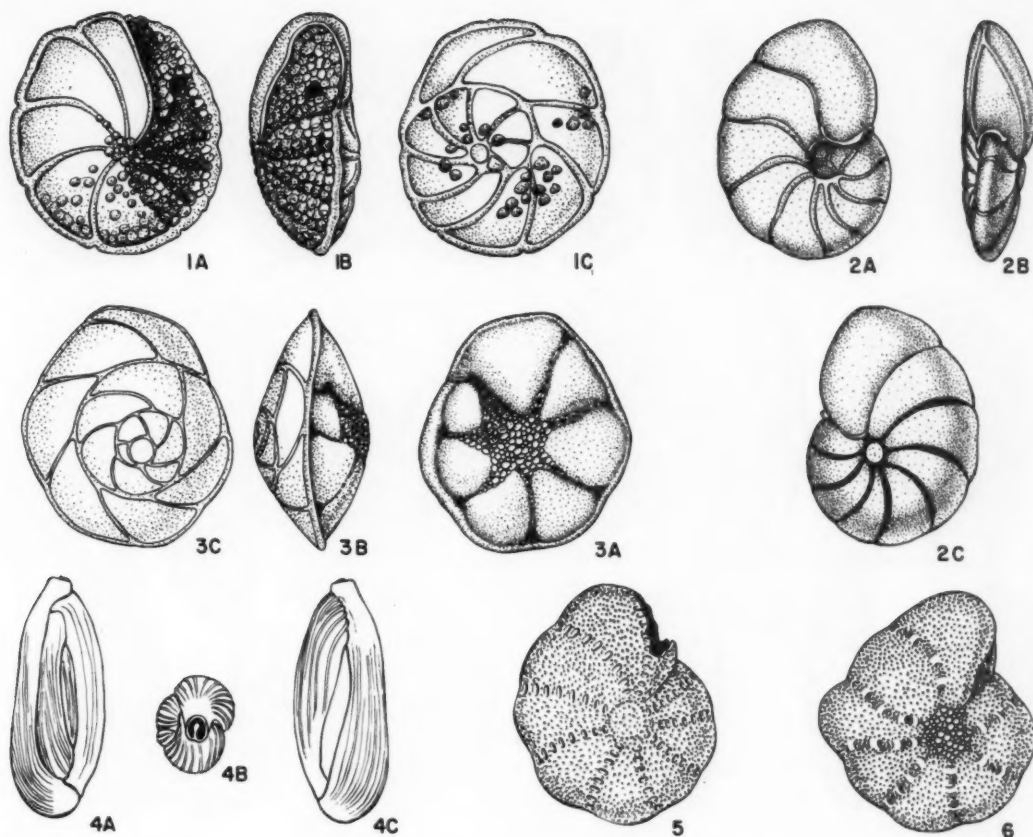


11B

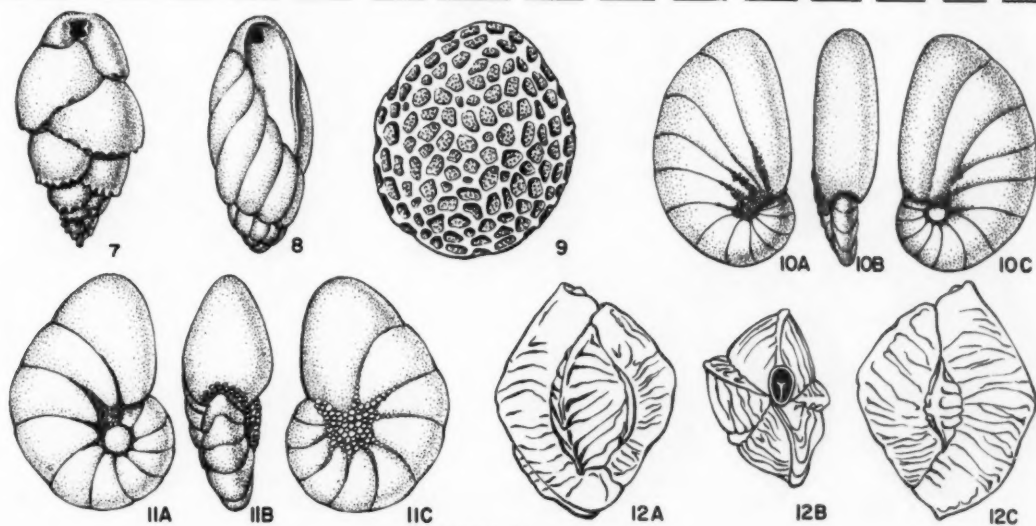


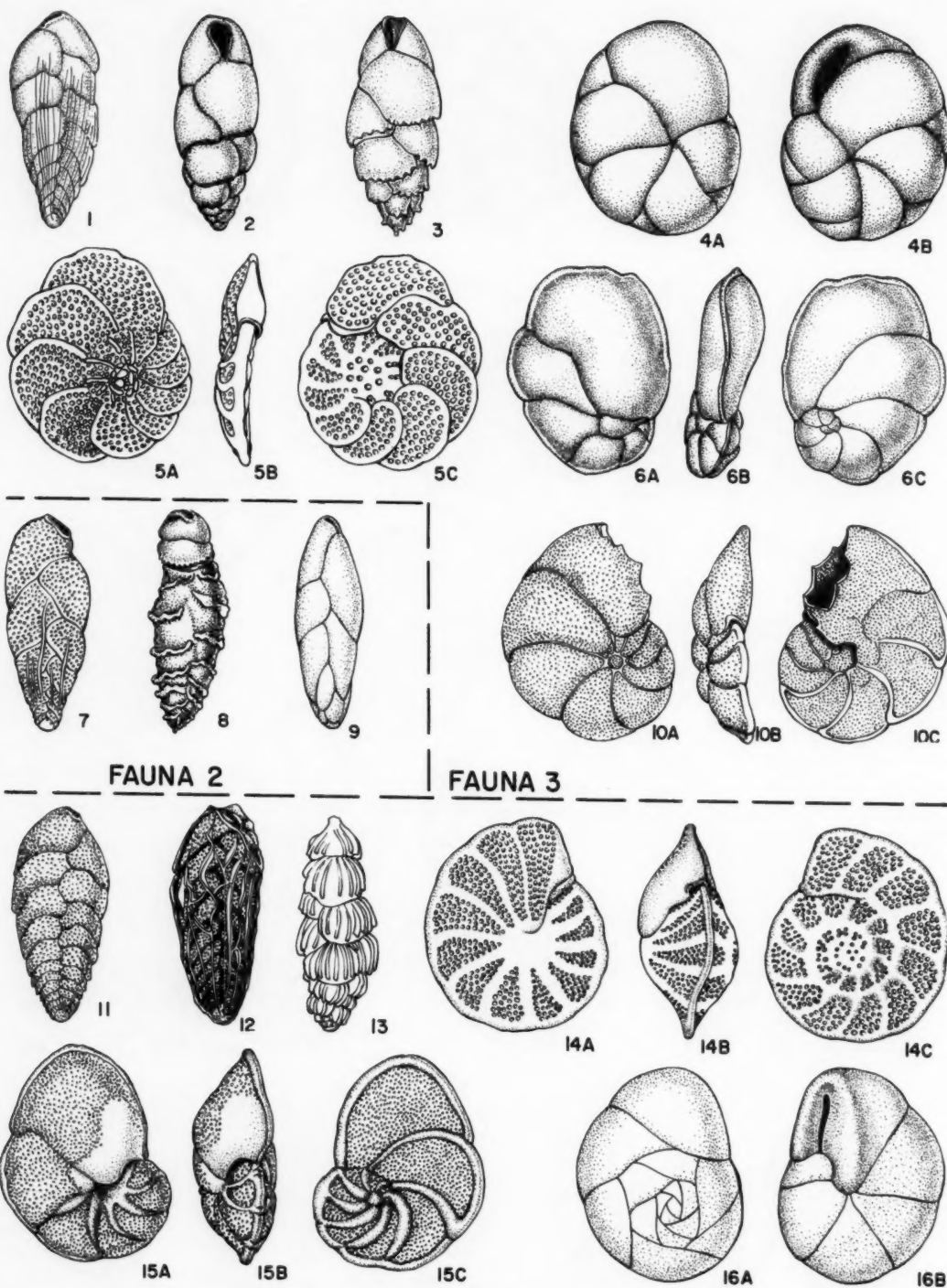
11A

FAUNA I



 FAUNA I


 FAUNA 2
 INNER SHELF BIOFACIES (FAUNAS 1-2)

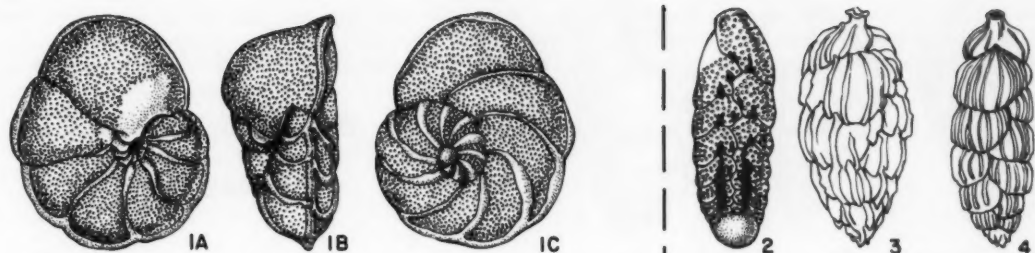


FAUNA 2

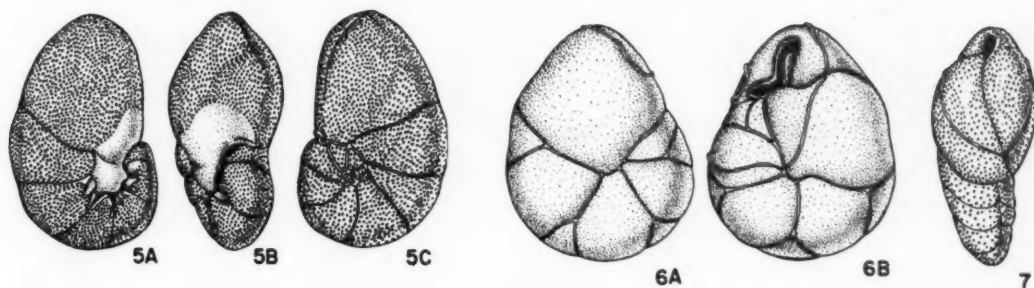
FAUNA 3

FAUNA 4

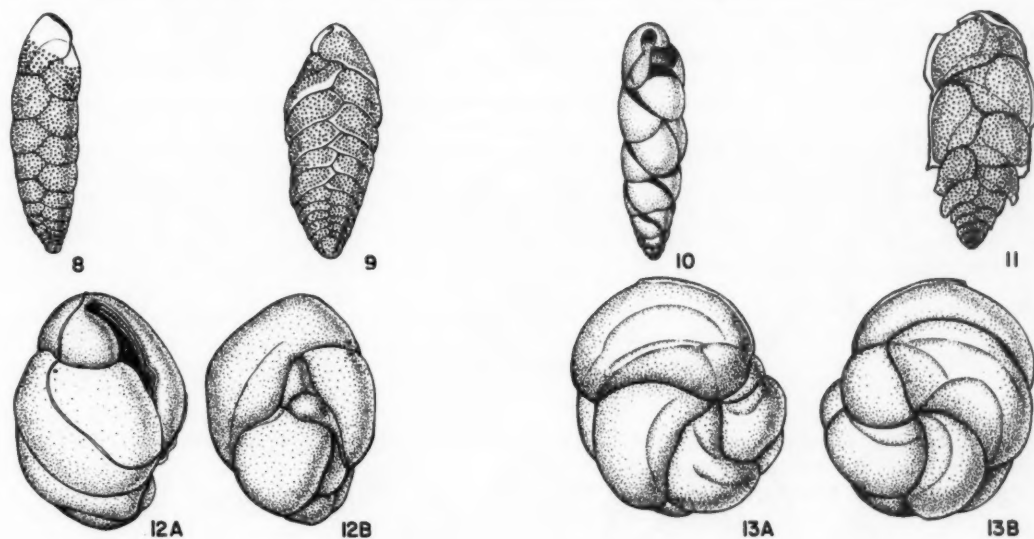
OUTER SHELF BIOFACIES (FAUNAS 3-4)



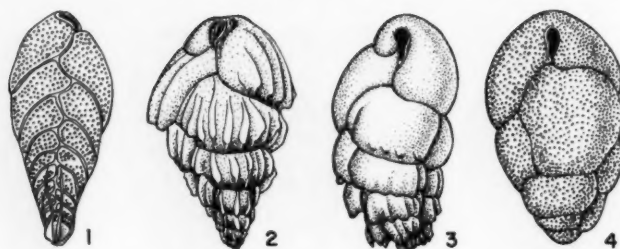
FAUNA 5



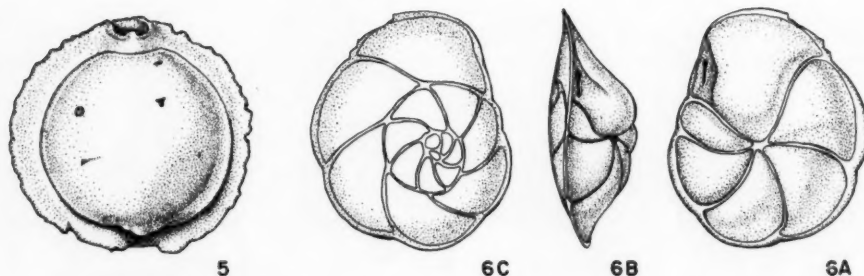
FAUNA 6



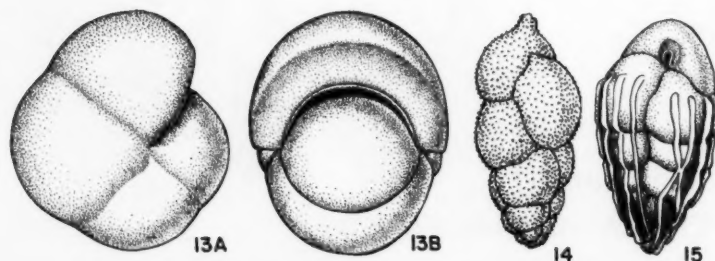
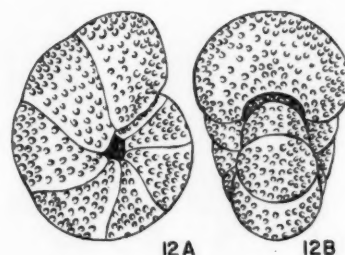
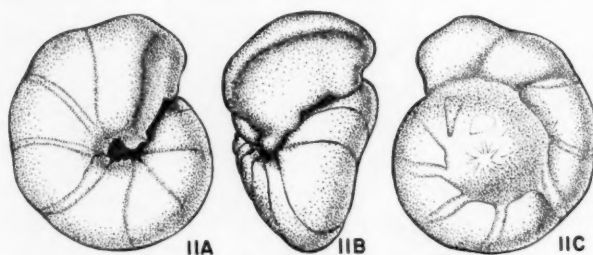
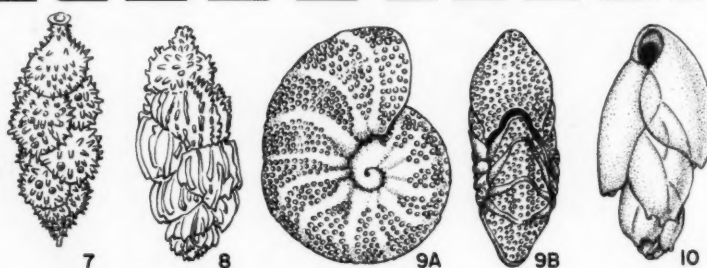
FAUNA 7
UPPER BATHYAL BIOFACIES
(FAUNAS 5-6-7)



UPPER MIDDLE
BATHYAL BIOFACIES
(FAUNAS 8-9-10)



LOWER MIDDLE
BATHYAL BIOFACIES
(FAUNAS 11-12-13)



LOWER BATHYAL
BIOFACIES
(FAUNAS 14-15)

ABSTRACT *Microspores are described from three representative rock samples from the Billefjorden sandstones of the Lower Carboniferous of central Vestspitsbergen. The age of this series is considered to range from Tournaisian to at least Viséan and perhaps Namurian. One new genus, Velosporites, and thirteen new species are erected. Several species are shown to resemble previously described Russian, Canadian and Scottish types.*

Palynological reconnaissance of the Lower Carboniferous of Spitsbergen

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Cambridge, England*

INTRODUCTION

The purpose of this paper is to give a preliminary account of an important Lower Carboniferous microflora from Spitsbergen. A comprehensive study of a much greater range of material is now being made by one of us (G.P.).

A part of the Lower Carboniferous (or Culm) succession of Spitsbergen in the Isfjorden area has been studied by Cambridge Spitsbergen expeditions. The age of some of these rocks has been determined approximately from the plant macrofossil evidence, and the term Billefjorden sandstone has been given to this part of the Central Vestspitsbergen succession (Forbes, Harland and Hughes, 1958). These authors record local stratigraphical references, and express the view that the Spitsbergen Culm includes beds of Tournaisian, Viséan, and perhaps also Namurian age; this view is endorsed and strengthened by the microfossil evidence here presented.

The previous work on this subject consists of a paper by Lubert (1935) in which she figured, but did not describe or name, a few microspores comparable with ours from the Culm of Pyramiden which lies west of Billefjorden in the same general area. She recorded a very general resemblance to the microflora of the Moscow and other Russian coal basins.

We wish to record our gratitude to Mrs. Margaret Mortimer who carried out much of the preparation work and was involved in the early part of the investigation; the new species of *Knoxosporites* is named in recognition of her contribution. Geoffrey Playford is undertaking his research in Cambridge during the tenure of a Robert and Maude Gledden Research Fellowship from the University of Western Australia.

PREPARATION OF MATERIAL

Clastic sediment samples were given a standard treatment with hydrofluoric, dilute hydrochloric and concentrated nitric acids. The coal was treated with fuming nitric acid. Alkali was not used and the general large size of the spores is not believed to result from any swelling in preparation. Many of the spores are very well preserved. More gentle treatments which reduce the use of strong acids were not employed, as most of the preparations were made in 1958. All preparations (including some single mounts) are mounted, unstained, in glycerine jelly.

As will be seen from the tables given below, no attempt has been made to comment on all the spores present in the samples. New species have not been erected unless ten or more good specimens were available; even this number often failed to produce specimens really suitable for detailed examination or photography.

Counting has been restricted to approximately 250 spores per sample; this was considered adequate for the present purpose.

SAMPLES

The Billefjorden sandstones are typically sandstones, but contain subordinate dark siltstones, shales and coals. The following three samples have been selected, with details as follows:

1) Sample B685 is a carbonaceous and micaceous fine-grained massive sandstone from locality B619, which is low in the succession on the eastern face of Citadellet, Dicksonland. It was collected by Mr. B. Moore in 1955. The details of the microflora, which is unusually well preserved, are recorded in Table 1.

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TABLE 1

MICROSPORE SPECIES PRESENT IN SAMPLE B685

Spore	%	Previous records and remarks	Age indication
<i>Leiotriletes inermis</i> (Waltz) Potonié and Kremp	2.0	Luber & Waltz (1938), Lower Carboniferous; Ishchenko (1956, 1958), Upper Devonian-Moscovian	—
<i>Lophotriletes coniferus</i> sp. nov.	0.8	—	—
<i>Convolutispora vermiformis</i> sp. nov.	3.6	Hacquebard (1957), <i>C. flexuosa</i> f. <i>minor</i> from lowermost Mississippian	Tournaisian
<i>Reticulatisporites planus</i> sp. nov.	2.0	—	—
<i>Knoxisporites margarethae</i> sp. nov.	3.2	—	—
<i>Knoxisporites cinctus</i> (Waltz) Butterworth and Williams	3.2	Luber & Waltz (1938), Lower Carboniferous; Butterworth & Williams (1958, upper part of Limestone Coal Gp. (Namurian A), but spores of different size.	Lower Carboniferous
<i>Perotriletes perinatus</i> sp. nov.	1.2	—	—
<i>Perotriletes magnus</i> sp. nov.	2.4	—	—
<i>Tripartites incisorilobus</i> (Naumova) Potonié and Kremp	0.4	Ishchenko (1956, 1958), Tournaisian-Namurian; Butterworth & Williams (1958), Limestone Coal Gp., etc.	Lower Carboniferous
<i>Stenozonotriletes clarus</i> Ishchenko	1.6	Ishchenko (1958), Upper Devonian-Viséan of Dnieper-Donetz Basin	—
<i>Annulatisporites labiatus</i> sp. nov.	6.0	Comparable species: <i>Labiadensites attenuatus</i> Hacquebard & Barss, 1957, ?Viséan; <i>L. fimbriatus</i> (Waltz) Hacquebard & Barss 1957, Lower Carboniferous (Luber & Waltz, 1938), Tournaisian and Viséan (Ishchenko, 1956, 1958).	Lower Carboniferous
<i>Densosporites striatiferus</i> sp. nov.	0.4	—	—
<i>Lophozonotriletes triangulatus</i> sp. nov.	9.2	Ishchenko (1956), records as variety, Tournaisian C1/1.	Tournaisian.
<i>Lophozonotriletes dentatus</i> sp. nov.	1.6	—	—
<i>Tholisporites foveolatus</i> sp. nov.	46.0	Hacquebard (1957), record 4 spp. of comparable <i>Vallatisporites</i> from lowermost Mississippian.	Tournaisian.
<i>Velosporites echinatus</i> gen. et. sp. nov.	5.2	—	—
<i>Endosporites micromanifestus</i> Hacquebard	0.4	Hacquebard (1957), lowermost Mississippian	Tournaisian.

Other spores seen include *Calamospora* sp., (2.0%), *Punctatisporites* sp., (2.0%), *Cyclogranisporites* (1.2%), *Granulatisporites* sp. (0.4%), *Apiculatisporites* sp., *Acanthotriletes* sp. (0.8%). The remainder of the assemblage was indeterminable.

TABLE 2

MICROSPORE SPECIES PRESENT IN SAMPLE S59a

Spore	%
<i>Chaetosphaerites pollenisimilis</i> (Horst) Butterworth & Williams	0.6
<i>Leiotriletes</i> sp.	1.3
<i>Punctatisporites</i> sp.	0.6
<i>Calamospora</i> sp.	1.0
<i>Granulatisporites</i> sp.	1.3
<i>Convolutispora clavata</i> (Ishchenko), comb. nov.	1.0
<i>Convolutispora</i> sp.	0.6
<i>Triquitrites batillatus</i> sp. nov.	18.2
<i>Triquitrites</i> sp.	1.0
<i>Tripartites</i> sp.	0.6
<i>Lycospora</i> sp.	0.6
<i>Anulatisporites</i> cf. <i>anulatus</i> (Loose) Potonié & Kremp	9.4
<i>Densosporites variabilis</i> (Waltz) Potonié & Kremp	40.2
<i>Densosporites dentatus</i> (Waltz) Potonié & Kremp	15.6
<i>Cincturasporites literatus</i> (Waltz) Hacquebard & Barss	1.7
<i>Cincturasporites auritus</i> (Waltz) Hacquebard & Barss	1.0
Indeterminate	5.3

TABLE 3

MICROSPORE SPECIES PRESENT IN SAMPLE B609

Spore	%
<i>Leiotriletes</i> sp.	0.8
<i>Punctatisporites</i> sp.	2.0
<i>Calamospora</i> sp.	1.2
<i>Granulatisporites</i> sp.	3.2
<i>Convolutispora</i> spp. indet.	3.2
<i>Reticulatisporites</i> sp.	1.6
<i>Triquitrites</i> sp.	1.2
<i>Tripartites incisorilobus</i> (Naumova) Potonié & Kremp	1.2
<i>Lycospora</i> cf. <i>pusilla</i> (Ibrahim) Schopf, Wilson & Bentall	43.2
<i>Simozonotriletes intortus</i> (Waltz) Potonié & Kremp	5.6
<i>Anulatisporites? anulatus</i> (Loose) Potonié & Kremp	20.4
<i>Cincturasporites auritus</i> (Waltz) Hacquebard & Barss	5.6
<i>Diatomozonotriletes saetosus</i> (Hacquebard & Barss), comb. nov.	0.8
<i>Endosporites</i> sp.	1.2
Indeterminate	8.8

FOSSIL MICROFLORA OF SPITSBERGEN

2) Sample S59a is a coal from the north side of Wordiekammen, northeast Billefjorden; the Billefjorden sandstones are approximately 850 feet thick in this locality, and the sample was collected 620 feet above base by Dr. O.P. Singleton on the 1949 expedition. The microflora of this coal, listed on Table 2, shows less diversity of species than that of the clastic sediments, as has been shown elsewhere.

3) Sample B609 is a carbonaceous siltstone from locality B603 on the south side of Ebbadalen, northeast Billefjorden, and was also collected by Moore in 1955. It comes from just above the highest coal near the base of the Lower Gypsiferous series, and bears a plant macrofossil, *Cardiopteridium? spitsbergense* Nathorst (Forbes, Harland and Hughes, 1958). The microflora, listed in Table 3, proved to be the least well preserved, but was collected from about the same horizon as the coal S59a, and is therefore complementary to it.

The following preparations were used: M811, M928, M949, P003 (from sample B685); M883, P150 (from sample S59a); and M803 (from sample B609).

AGE OF SAMPLES

From the examination of sample B685 (see Table 1), we conclude that this lower part of the series is probably of Tournaisian age, although it must be pointed out that the correlation is indirect and has not been proved to northwestern Europe, the type area of the stage. In this connection, the occurrence of the Russian form *Lophozonotriletes triangulatus*, new species, is more significant than the suggested correlation with Hacquebard's (1957) lowest Mississippian Horton series. Butterworth and Williams (1958) did not examine beds lower than Namurian, and the downward range of their spore species in Britain has not been published. Luber and Waltz (1938), and Ishchenko (1956, 1958) on the other hand have examined spores from rocks ranging through the whole of the Lower Carboniferous.

The precise position of sample B685 with respect to the local base of the Billefjorden sandstones is not known because of scree cover, but other sections subsequently sampled in the same general area are expected to give more precise information on the age of the base of the series.

The microspore assemblages of samples S59a and B609 (see Tables 2 and 3, respectively) are believed to be of upper Viséan or possibly lowermost Namurian age, by comparison with Viséan-Namurian microfloras reported previously from Russia (Luber and Waltz, 1938; Ishchenko, 1956, 1958), Scotland (Butterworth and Williams, 1958), and Canada (Hacquebard and Barss, 1957). Species of *Densosporites* and the related *Anulatisporites*, together with *Lycospora* and *Triquitrites* occur in abundance. *Diatomozonotriletes saetosus* (Hacquebard and Barss), new combination, and *Convolutispora clavata* (Ishchenko), new combination, are significantly post-Tournaisian species (Ishchenko 1956, 1958). These two

samples are from near the top of the Billefjorden sandstones where they are overlain conformably (in the Ebbadalen area) by the Lower Gypsiferous series; further samples now available are expected to make it possible to date this boundary more precisely.

REMARKS ON THE MICROFLORA

The Upper Devonian microfloras of Naumova (1953) were mainly of Frasnian age. The principal sculptured forms were species of her subgroups *Lophozonotriletes*, *Acanthotriletes*, *Hymenozonotriletes* (some slightly resembling *Tholisporites* and *Vallatisporites*), and *Archaeoperisaccus*, for which we have found no parallel. Her Famennian flora, which was sparser, included, at the top *Archaeozonotriletes dedaleus*, which approaches the form of *Knoxisporites*.

Our Tournaisian flora (B685) is dominated by cingulate or bordered forms, particularly with relatively coarser detailed sculpture (reticulate, convolute and lophate); these are little removed from the Upper Devonian types and probably represent mostly Lycopsida with subordinate Primofilices and Eusporangiate ferns. The new elements are the perinate and monosaccate forms, the latter principally Extrornati of perhaps pteridosperm origin.

The macroflora, as represented by the collections from the Billefjorden sandstones recorded by Forbes, Harland and Hughes (1958) and by Nathorst (1914) from this and other Culm successions, shows a predominance of remains of *Lepidodendron* and the Sublepidodendron group, with relatively few macrophyllous leaves which may well be mostly of pteridosperm origin.

The younger microfloras (S59a and B609) have a more typically Carboniferous and less Devonian aspect than the Tournaisian assemblage (B685), and it is probable that important vegetational evolution occurred within the time represented by the Billefjorden sandstones. The absence of monolet spores (*Laevigatosporites*) is noteworthy.

TAXONOMY

We have attempted to provide several illustrations of most species, and we believe that both photographs and diagrams may be necessary in difficult cases. Much of the difficulty and waste of time in interpreting published taxa would be removed if authors were allowed and encouraged to present more figures of each species, properly annotated as to focus and orientation. This could even help to reduce the annual output of new species.

Some of our species are obviously similar to forms described from Russia, but many of the Russian species are inadequately figured and the types have not been seen. Consequently, perhaps too many new species have been erected. On the other hand, we feel that in most cases sufficient generic names already exist, although their actual diagnoses are often far from satisfactory. In

some instances we have pointed out these deficiencies, but have deferred emendation of the genera.

Descriptions of already published species have been given in several cases to amplify too brief original descriptions or in cases where we feel certain that corrosion, either natural or in preparation, has affected the originally described forms.

SYSTEMATIC DESCRIPTIONS

The genera are arranged in higher groups according to the independent morphographic system of Potonié (1956, 1958). We consider this system a valuable aid in classifying taxa which are principally form-genera and only occasionally organ-genera.

Type and other identifications are made by reference to slide (preparation) number, followed by "east-west" and then "north-south" mechanical stage readings; these readings refer to Leitz Dialux microscope no. 1 in the Department of Geology, Sedgwick Museum, Cambridge, where the material is deposited.

Anteturma SPORONITES (R. Potonié) Ibrahim, 1933
Genus CHAETOSPHAERITES Felix, 1894

Chaetosphaerites pollenisimilis (Horst) Butterworth and Williams

Occurrence: Sample S59a; rare. Recorded from the Namurian by Horst (1955) and Butterworth and Williams (1958).

Discussion: We agree with Butterworth and Williams (1958) that these spores are probably of fungal origin, but are uncertain of the suitability of this generic name.

Anteturma SPORITES Potonié, 1893
Turma TRILETES (Reinsch) Potonié and Kremp, 1954
Subturma AZONOTRILETES Luber, 1935
Infraturma LAEVIGATI (Bennie and Kidston) Potonié and Kremp, 1954
Genus LEIOTRILETES (Naumova) Potonié and Kremp, 1954

Leiotriletes inermis (Waltz) Potonié and Kremp Plate 1, figure 1

Occurrence: Sample B685. Recorded previously by Luber and Waltz (1938), Luber (1955) and Ishchenko (1956, 1958) who indicates a range of Upper Devonian to Moscovian for the species.

Infraturma APICULATI (Bennie & Kidston) Potonié, 1956
Genus LOPHOTRILETES (Naumova) Potonié and Kremp, 1954

Lophotriletes coniferus Hughes and Playford, new species Plate 4, figure 13

Diagnosis: Spores radial, trilete; amb convexly subtriangular (with rounded apices) to subcircular.

Laesurae distinct, slightly raised, sometimes folded, length approximately $\frac{3}{4}$ spore radius. Exine 3.5–7 μ thick; sculpture densely infrapunctate to infragranulate; together with numerous, small, fairly widely spaced conii, up to 2 μ high, usually about 4 μ apart. One or two coarse folds often present.

Dimensions: (12 specimens) Equatorial diameter 70–105 μ (mean 92 μ).

Holotype: Preparation M811/1, 49.8 110.7 Dialux 1.

Locus typicus: Sample B685, Lower Carboniferous, Spitsbergen.

Description: Holotype 105 μ in longest diameter; subtriangular with rounded apices and straight to slightly convex inter-radial margins; laesurae distinct, slightly raised and folded, length $\frac{4}{5}$ spore radius; exine 4.5 μ thick.

Comparison: Distinct from *Apiculatisporites maculosus* (Knox) Potonié and Kremp, 1955, which has a circular equatorial outline and papillate sculpturing elements.

Infraturma MURORNATI Potonié and Kremp, 1954

Genus CONVOLUTISPORIA Hoffmeister, Staplin and Malloy, 1955

Convolutispora vermiformis Hughes and Playford, new species Plate 1, figures 2–4

Diagnosis: Spores radial, trilete, originally spherical; amb subcircular. Laesurae straight to slightly sinuous, attain equatorial margin. Exine coarsely lophate to lophoreticulate; ridges 4–12 μ wide and 4–6 μ high, smooth and sinuous; lumina when present rounded to polygonal, 4–21 μ in diameter. Exine (excluding ridges) 2.5–4 μ thick.

Dimensions: Equatorial diameter (25 specimens) 57–73 μ (mean 64 μ).

Holotype: Preparation M811/3, 51.4 95.8 Dialux 1.

Locus typicus: Sample B685, Lower Carboniferous, Spitsbergen.

Description: Holotype diameter 60 μ , laesurae slightly sinuous, ridges closely packed, 8 μ high and 4 μ wide, lumina 10 μ wide, exine thickness 4 μ . Laesurae sometimes appear labiate, being delimited by the broad sculptural elements which often obscure the laesurae altogether.

Comparison: This species compares closely with *Convolutispora flexuosa* forma *minor* Hacquebard, 1957, which was described from only two specimens. *Convolutispora vermiformis*, new species, differs from *Periplecotriletes amplexus* forma *kasachstanensis* (Luber) Ishchenko, 1956, in having a coarser convoluted sculpture and longer laesurae.

Convolutispora clavata (Ishchenko),
new combination
Plate 1, figures 7–8

Lophotriteles clavatus Ishchenko, 1956, p. 43, pl. 6, fig. 82.

Description of specimens: Spores radial, trilete, originally spherical; amb circular to subcircular. Laesurae straight, length $\frac{1}{2}$ – $\frac{3}{4}$ spore radius. Exine thick (4.5–6 μ), densely sculptured with low, flattened, irregular verrucae or slightly anastomosing ridges about 2 μ high and 4 μ wide.

Dimensions: (14 specimens) diameter 96–126 μ (mean 110 μ). This size range exceeds Ishchenko's upper limit for the species by 16 μ .

Occurrence: Sample S59a. Ishchenko (1956, 1958) considers this species to be restricted to the Viséan.

Genus RETICULATISPORITES (Ibrahim) Potonié and Kremp, 1954

Reticulatisporites planus Hughes and Playford,
new species
Plate 1, figures 5–6; text-figure 1

Diagnosis: Spores radial, trilete; amb circular to subcircular. Laesurae simple, straight, extending almost to periphery. Sculpture coarsely reticulate with muri 4–15 μ wide and 4–6 μ high, enclosing subcircular to irregularly polygonal lumina 2–23 μ in longest diameter. Muri dumbbell-shaped in optical section (text-fig. 1), and give rise to broad flat ridges. Exine thickness (exclusive of muri) 2.5–4.5 μ .

Dimensions: (14 specimens) Equatorial diameter 63–86 μ (mean 76 μ).

Holotype: Preparation M811/1, 31.1 113.9 Dialux 1.

Locus typicus: Sample B685, Lower Carboniferous, Spitsbergen.

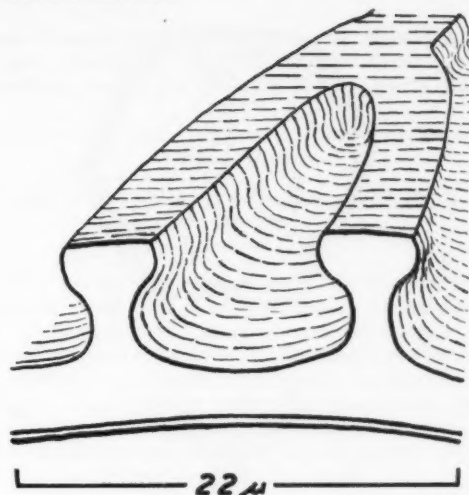
Description: Holotype diameter 76 μ ; subcircular. In some specimens the muri do not always link to delimit distinct lumina.

Comparison: *Reticulatisporites evolvens* (Waltz) Potonié and Kremp 1955 has a more regular reticulum, larger lumina and an irregularly indented equatorial margin. *R. evolvens* was figured (pl. 1, fig. 9) but not described by Luber and Waltz (1938); therefore, a more precise comparison is precluded.

Genus KNOXISPORITES Potonié and Kremp, 1954

Knoxisporites margarethae Hughes and Playford,
new species
Plate 1, figures 9–14; text-figure 2

Diagnosis: Spores radial, trilete; amb subcircular to polygonal. Laesurae strongly labiate, straight, length approximately $\frac{2}{3}$ spore radius; labiae with undulating



TEXT-FIGURE 1

Reticulatisporites planus sp. nov. Diagram showing optical section of sculptural elements (muri).

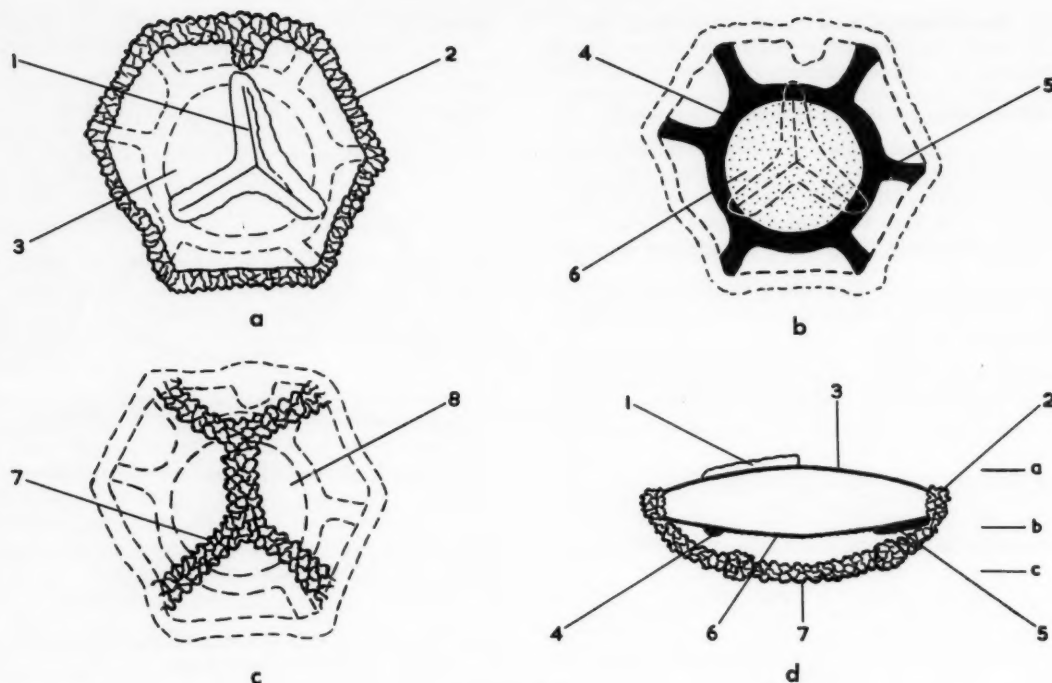
outer margins, extending 5–16 μ (average 7 μ) on either side of laesurae. Equatorial margin with frilled border 4–6 μ wide, giving distinctive "pie-crust" appearance. Proximal hemisphere (excluding border) laevigate. On distal hemisphere, prominent dark ring sharply prescribes infragranulate central area of diameter 37–73 μ (mean 53 μ) from laevigate outer area; ringlike thickening is approximately 5 μ wide and from it several straight bars (of similar width) emanate radially to the frilled border. Additional, distinctive, heavy, elevated reticulum encompasses distal hemisphere, arising from the frilled equatorial border which serves as its only attachment to the spore. The bars of this outer distal reticulum appear to constitute a domed extension of the frilled (pie-crust) spore border, being similarly entirely frilled (or having a central smooth region with marginal frilling); bars 6–15 μ in diameter, roughly circular in cross section. Arrangement and density of this reticulum regular to highly irregular.

Dimensions: (24 specimens) Equatorial diameter 75–104 μ (mean 90 μ).

Holotype: Preparation M928/5, 57.1 111.7 Dialux 1.

Locus typicus: Sample B685, Lower Carboniferous, Spitsbergen; abundant.

Description: Holotype 85 μ , amb hexagonal, frilled border 4 μ wide. Laesurae directed to alternate sides of hexagon, labiae 5 μ wide. Distal central area 42 μ in diameter, thickened ring 6 μ with six radial bars (6 μ wide) extending to hexagonal angles. Frilled bars of outer distal reticulum 6 μ thick, arrangement in this case simple and symmetrical (see text-fig. 2). Another specimen showed a distal reticulum of three radial bars rotated through



TEXT-FIGURE 2

Diagrams of *Knoxisporites margarethae* sp. nov. $\times 500$. a-c: Holotype (proximal view) illustrating three levels of focus; a) high focus (proximal surface), b) central focus (distal surface), c) low focus; d) Generalized hypothetical polar section (not specifically of holotype).

Explanation: 1) labiate laesura; 2) frilled border; 3) laevigate proximal surface; 4) thickened distal ring; 5) distal radial bar; 6) infragranulate distal central area; 7) domed distal reticulum attached to spore only at frilled border; 8) lumen of reticulum. See also photographs of holotype (pl. 1, figs. 9-11) from which a-c were drawn.

60° with respect to the laesurae, but symmetrical arrangements are unusual. Some specimens have a proximal extension of the distal outer reticulum, but it is less strongly developed than on the distal side.

Comparison: A new, highly distinctive species of *Knoxisporites*, characterised by complexity of reticulation and thickening.

Knoxisporites cinctus (Waltz) Butterworth and Williams, 1958
Plate 2, figures 1-4

Description: Spores radial, trilete; amb circular to sub-circular. Laesurae strongly developed, labiate, length approximately equal to radius of spore body; lips extending 4-7 μ on either side of laesurae, slightly raised, with straight to undulating outer margins. Thickened border relatively narrow, with smooth equatorial margin. Reticulum heavy, irregular, re-

stricted to distal hemisphere. Muri 3-8 μ wide (average 5 μ), 7-12 μ high, arising from distal surfaces of both spore body and border. Lumina sub- to irregularly rounded, 8-26 μ in diameter. Apart from distal reticulum, exine of spore body thin, usually laevigate, occasionally infrapunctate or infragranulate; exine of border approximately 4 μ thick, laevigate.

Dimensions: (16 specimens) Overall equatorial diameter 58-94 μ (mean 75 μ); diameter of spore body 46-67 μ (mean 58 μ); width of border 6-14 μ (mean 9 μ).

Occurrence: Sample B685. Recorded previously by Luber and Waltz (1938) and Butterworth and Williams (1958).

Discussion: We agree with Butterworth and Williams (1958, p. 370) concerning the assignment of this species to *Knoxisporites*. Their Scottish specimens, however, are notably smaller (40-60 μ) than the Spitsbergen representatives described above.

FOSSIL MICROFLORA OF SPITSBERGEN

Infraturma PERINOTRILITI Erdtman, 1947
Genus PEROTRILITES Erdtman ex Couper, 1953

Perotrilites perinatus Hughes and Playford,
new species

Plate 2, figures 7-10

Diagnosis: Spores radial, trilete; amb circular to triangular, usually convexly subtriangular. Perine very thin, hyaline, laevigate to finely granulate, loose-fitting, usually wrinkled and folded, standing out 4-10 μ beyond equatorial margin of spore body. Laesurae 2/3 to 5/6 radius of spore body, straight and sometimes with weak, narrow labiae. Exine laevigate, thickness 2.5-4 μ .

Dimensions: (16 specimens) Equatorial diameter (excluding perine) 44-90 μ (mean 67 μ).

Holotype: Preparation P003/4, 42.8 95.1 Dialux 1.

Locus typicus: Sample B685, Lower Carboniferous, Spitsbergen.

Description: Holotype diameter 62 μ (excluding perine); amb subtriangular with rounded apices and slightly convex sides; perine standing out 4 μ from spore body equator; laesurae distinct, length 5/7 spore body radius; exine 3 μ thick.

Comparison: Resembles some spores of the Recent *Selaginella sibirica* group figured by Knox (1950, pl. 9, figs. 76-77).

Perotrilites magnus Hughes and Playford,
new species

Plate 2, figures 5-6

Diagnosis: Spores radial, trilete; amb rounded triangular to subcircular. Perine very thin, hyaline, laevigate to infragranulate, relatively close-fitting (usually about 6 μ beyond spore body equator), weakly folded. Laesurae straight, simple, extending for approximately $\frac{1}{2}$ - $\frac{3}{4}$ of the radius of the spore body. Exine thin (1.5-2.5 μ), laevigate, frequently broadly folded owing to compression.

Dimensions: (16 specimens) Equatorial diameter (excluding perine) 98-156 μ (mean 122 μ).

Holotype: Preparation M928/1, 39.0 92.9 Dialux 1.

Locus typicus: Sample B685, Lower Carboniferous, Spitsbergen.

Description: Holotype 155 μ in diameter; amb subcircular, closely enveloped by infragranulate perine; laesurae distinct, length approximately $\frac{3}{4}$ spore body radius; exine 2 μ thick, with several large folds.

Comparison: This species differs from *P. perinatus* in its largesize, in its thinner exine which results in the characteristic compression folds of the spore body, and in its shorter laesurae.

Turma ZONALES (Bennie and Kidston) Potonié, 1956
Subturma AURITOTRILETES Potonié and Kremp, 1954
Infraturma AURICULATI (Schopf) Potonié and Kremp, 1954

Genus TRIQUITRITES (Wilson and Coe) Potonié and Kremp, 1954

Triquitrites batillatus Hughes and Playford,
new species

Plate 2, figures 11-14

Diagnosis: Spores radial, trilete; amb subtriangular with prominent, solid, dark, subequal, shovel-shaped auriculae having smooth margins and developed on rounded apices of spore body. Radial length of auriculae ranges from 9-21 μ (mean 16 μ) which is approximately half their width. Spore body coat smooth or infragranulate, 1 μ thick; interrational margins \pm straight, entire. Laesurae prominent, straight, simple, length equal to $\frac{3}{4}$ or more of spore body radius.

Dimensions: (25 specimens) Overall equatorial diameter 45-73 μ (mean 59 μ), spore body diameter 34-56 μ (mean 43 μ).

Holotype: Preparation P150/3, 19.3 101.0 Dialux 1.

Locus typicus: Sample S59a, Lower Carboniferous, Spitsbergen; abundant.

Description: Holotype 67 μ , spore body diameter 50 μ ; interrational margins slightly concave; smooth, dense auriculae approximately 28 μ \times 15 μ in proximal view; exine 1 μ thick, infragranulate; laesurae extend almost to auriculae. Auriculae usually have entire or slightly undulating equatorial outline, but in poorly preserved specimens a ragged outline is sometimes apparent.

Comparison: This species is characterised by its large, prominent, shovel-shaped auriculae, which are not connected by an equatorial flange. It is distinct from *Triquitrites triturgidus* (Loose) Potonié and Kremp which is poorly figured but which has \pm swollen semicircular auriculae and typically strongly concave interrational outline; also from *T. pulvinatus* Kosanke 1950 which has cushion-shaped auriculae similar to *T. triturgidus*. *Triquitrites bransonii* Wilson and Hoffmeister 1956 with a size range of 30-40 μ is consistently smaller than *T. batillatus*.

Genus TRIPARTITES Schemel, 1950

Tripartites incisotrilobus (Naumova) Potonié and Kremp

Plate 2, figure 15

Occurrence: Samples B685 and B609, Lower Carboniferous, Spitsbergen.

Discussion: Recorded elsewhere from Lower Carboniferous of the Moscow and Kizel Basins (Luber and Waltz, 1938); from Viséan of the Western Donetz Basin (Ishchenko, 1956); from Tournaisian-Namurian of the

Dneiper-Donetz Basin (Ishchenko, 1958); and from Namurian A of Scotland (Butterworth and Williams, 1958).

Subturma ZONOTRILETES Waltz, 1935

Infraturma CINGULATI Potonié and Klaus, 1954

Genus SIMOZONOTRILETES Naumova ex Potonié and Kremp, 1954

Simozonotriletes intortus (Waltz) Potonié and Kremp

Occurrence: Sample B609, Lower Carboniferous, Spitsbergen.

Discussion: Apparently widespread throughout the Northern Hemisphere, with records from the Dinantian (Luber and Waltz, 1938; Ishchenko, 1956, 1958; Hacquebard and Barss, 1957), Namurian/Westphalian A (Horst, 1955; Dybová and Jachowicz, 1957; Butterworth and Williams, 1958), and recently from as high as middle Westphalian B (Sullivan, 1958). The stratigraphical range table of Ishchenko (1956) indicates a lower limit (at the Tournaisian-Viséan boundary) which may well be valid.

Genus STENOZONOTRILETES (Naumova) Hacquebard, 1957

Stenozonotriletes clarus Ishchenko, 1958
Plate 3, figures 1-2

Description of specimens: Spores radial, trilete; amb convexly subtriangular to subcircular, smooth. Spore body with thin exine, laevigate or infrapunctate, encompassed equatorially by narrow, uniform, laevigate rim. Laesurae straight or slightly sinuous, length $\frac{4}{5}$ or more of spore body radius. In some specimens one interradial margin is more convex than the other two, resulting in a somewhat deltoid appearance.

Dimensions: (22 specimens) Overall equatorial diameter 47-80 μ (mean 61 μ); rim 4-7 μ wide (mean 5 μ).

Occurrence: Sample B685, Lower Carboniferous, Spitsbergen. Also (?Upper) Devonian, Tournaisian and Viséan of the Dneiper-Donetz Basin (after Ishchenko, 1958).

Comparison: The specimens conform closely to the description given by Ishchenko (1958, p. 86), except that they broaden the size-range considerably.

Remarks: The emendation of *Stenozonotriletes* Naumova, 1937, by Potonié (1958) is essentially similar to that stated earlier by Hacquebard (1957); both authors recognised the desirability of separating *Lycospora* (Schopf, Wilson and Bental) Potonié and Kremp, 1954, from Naumova's broad (1953) definition of her subgroup *Stenozonotriletes*.

Genus ANULATISPORITES Loose ex Potonié and Kremp, 1954

Anulatisporites labiatus Hughes and Playford,
new species

Plate 3, figures 14-17

Diagnosis: Spores radial, trilete; amb circular to convexly subtriangular. Distinct spore body and wide cingulum (width $\frac{1}{2}$ -1 \times radius of body). Laesurae straight, vary from $\frac{2}{3}$ to approximately the length of the body radius; strongly developed labiae (6-10 μ wide) with wrinkled outer margins, often extending some distance equatorially beyond laesurae. Central body laevigate to finely granulate; outer margin well-defined and conformable in shape with the smooth equatorial outline. Cingulum laevigate and slightly darker in colour than the body, generally of uniform appearance but may show poorly defined concentric zones of equatorially decreasing thickness.

Dimensions: (32 specimens) Overall equatorial diameter 71-132 μ (mean 102 μ), body diameter 42-88 μ (mean 61 μ), cingulum 12-30 μ (mean 21 μ).

Holotype: Preparation M811/2, 50.5 93.5 Dialux 1.

Locus typicus: Sample B685, Lower Carboniferous, Spitsbergen.

Description: Holotype subcircular, 116 μ overall diameter, entirely laevigate; spore body 56 μ in diameter, slightly lighter in colour than cingulum; laesurae narrow, straight, ornately labiate (lips 6 μ wide), length equal to spore body radius; cingulum 25 μ wide, with slight zonation effect.

Comparison: This species probably includes *Zonotriletes macrodiscus* Waltz, which was figured but not described by Luber and Waltz (1938), and also type 101 of Reinsch (1884, pl. 22, fig. 46D). It is distinct from *Labiadensites fimbriatus* (Waltz) of Hacquebard and Barss (1957) in that the cingulum is of fairly uniform thickness and its margin is smooth. *L. attenuatus* Hacquebard and Barss appears to us to be very close to *L. fimbriatus*. *A. labiatus*, new species, fails to conform to the diagnosis of *Labiadensites* Hacquebard and Barss despite its obvious general similarity with the above two species; therefore it is placed provisionally within the broad category of *Anulatisporites*.

Genus DENSOSPORITES (Berry) Potonié and Kremp, 1954

Discussion: In view of the unfortunate loss of the holotype of the type species (Wilson, 1959), and the large number of species in this genus, we support the proposal already made (Hughes) to the "International Commission for the Microflora of the Palaeozoic," that an "Infraturma Densosporiti" should be erected to include this and allied genera. To avoid creating more confusion we have decided not to anticipate the deliberations of that Commission and of other palynologists.

FOSSIL MICROFLORA OF SPITSBERGEN

Densosporites variabilis (Waltz) Potonié and Kremp
Plate 3, figures 11-13

Discussion: Numerous representatives of this structurally variable species were observed, and a continuous variation within the species, as diagnosed by Waltz (in Luber and Waltz, 1938), was confirmed.

Dimensions: (32 specimens) Overall equatorial diameter 41-69 μ (mean 56 μ), diameter of spore body 19-33 μ (mean 25 μ), width of cingulum 10-19 μ (mean 15 μ).

Occurrence: Sample S59a (preparation M883) Lower Carboniferous, Spitsbergen. Luber and Waltz (1938) record this species from the Tournaisian and Viséan of the Moscow and Kizel Basins; Ishchenko (1956) in his stratigraphical range table indicates Tournaisian, Viséan and Namurian occurrences; and Butterworth and Williams (1958) describe *D. variabilis* as being "abundant throughout" the Limestone Coal group and the Upper Limestone group (Namurian) of the Lower Carboniferous of Scotland.

Densosporites striatiferus Hughes and Playford,
new species
Plate 2, figures 16-18

Diagnosis: Spores radial, trilete; amb subtriangular. Laesurae straight reaching almost to margin of spore body. Spore body convexly subtriangular in polar view, 29-45 μ (mean 36 μ) in diameter; exine thin, finely punctate. Cingulum 7-12 μ wide, with irregularly undulating to lobed equatorial margin. Cingulum has distinctive radially striated appearance and is denser than spore body.

Dimensions: (12 specimens) Overall equatorial diameter 47-63 μ (mean 55 μ).

Holotype: Preparation M928/2, 40.3 109.2 Dialux 1.

Locus typicus: Sample B685, Lower Carboniferous, Spitsbergen.

Description: Holotype overall diameter 50 μ ; spore body 32 μ ; "striated" cingulum up to 12 μ wide with irregularly lobed equatorial margin; laesurae distinct, almost equal to spore body radius. The fine and closely spaced "striations" of the cingulum in this species are strikingly apparent from high to low focus; they seem to be a dense, radial arrangement of narrow elongated pits. Often, where the cingulum is of maximum width, the striated effect does not extend as far as the equatorial margin. It is important to point out the possibility that the frilled equatorial margin of the specimens included in this species may be the result of corrosion due to either weathering or the maceration process.

Remarks: This species is similar in general appearance to *Lophozonotriletes dentatus* sp. nov. but differs in possessing a characteristically striated cingulum, and lacking distal projections.

Genus **CINCTURASPORITES** Hacquebard and Barss, 1957

Cincturasporites literatus (Waltz) Hacquebard and Barss
Plate 3, figure 18

Dimensions: (17 specimens) Equatorial diameter 73-100 μ (mean 85 μ); this almost duplicates the size range given by Hacquebard and Barss (1957).

Occurrence: Sample S59a, Lower Carboniferous, Spitsbergen. Previous records of this species include those of Luber and Waltz (1938) from the Tournaisian and Viséan of the Moscow and Kizel Basins; Ishchenko (1956) from the Tournaisian and lower Viséan of the western Donetz Basin; Ishchenko, (1958) from the Upper Devonian-Namurian of the Dnieper-Donetz Basin; and Hacquebard and Barss (1957) from the Lower Carboniferous (probably Viséan) of the south Nahanni River area, Northwest Territories, Canada.

Cincturasporites auritus (Waltz) Hacquebard and Barss
Plate 3, figure 19

Dimensions: (20 specimens) Overall equatorial diameter 63-94 μ (mean 78 μ).

Occurrence: Samples S59a and B609, Lower Carboniferous, Spitsbergen. The species has been recorded previously by Luber and Waltz (1938) from the Tournaisian and Viséan of the Moscow and Kizel Basins; and by Hacquebard and Barss (1957) from probably Viséan coal of the south Nahanni River area, Northwest Territories, Canada.

Genus **LOPHOZONOTRILETES** (Naumova) Potonié, 1958

Discussion: This genus and *Galeatisporites* were discussed by Potonié (1958, p. 28) and neither is now strictly applicable to the two species described below. We believe, however, that these two species are close to some of those described by Naumova (1953) when she instituted this genus. The genus *Euryzonotriletes* Naumova, 1937, as used by other Russian authors (Ishchenko 1956, 1958), is considered to be too wide in meaning and it also lacks a designated type species (Potonié 1956, p. 87).

Lophozonotriletes triangulatus Hughes and Playford, **new species**
Plate 3, figures 3-7

Euryzonotriletes rarituberculatus (Luber) var. *triangulatus* Ishchenko, 1956, p. 51, pl. 8, fig. 104.

Diagnosis: As given by Ishchenko (1956).

Amplification of diagnosis: Spores radial, trilete; amb rounded triangular to subrounded, smooth to serrate.

Spore body and distinct cingulum, which is usually about 2/5 radius of central body, and of similar density. Laesurae simple, straight to slightly sinuous, extending almost to body margin. Distal surface laevigate to granulate, prominently sculptured with 4-16 (average 10) solid rounded tubercles: maximum basal diameter 4-23 μ (average 9 μ), length 6 μ , diameter at top 5-8 μ . Exine of the proximal hemisphere smooth to strongly granulate (particularly on the spore body).

Dimensions: (20 specimens) Overall equatorial diameter 52-77 μ (mean 65 μ); diameter of spore body 39-59 μ (mean 47 μ); cingulum width 6-12 μ (mean 9 μ).

Holotype: Specimen designated by Ishchenko for the variety (see Kremp, Ames and Kovar, 1959).

Description of specimens: Distribution of tubercles somewhat irregular but their observed occurrence includes (a) on spore body only, (b) on spore body and also in a marked concentration around the inner margin of the cingulum as a dark, more or less continuous ring, (c) irregularly over both spore body and cingulum.

Discussion: This form, described initially by Ishchenko (1956) as a variety, is elevated to specific status as it occurs alone in considerable numbers in sample B685.

Lophozonotriletes dentatus Hughes and Playford,
new species

Plate 3, figures 8-10

Diagnosis: Spores radial, trilete; amb convexly sub-triangular. Cingulum slightly denser than, and $\frac{1}{3}$ - $\frac{1}{2}$ radius of, spore body. Laesurae simple, straight, extending almost to body margin. Prominent large, simple or compound processes, basal diameter 4-19 μ and length 4-14 μ , are irregularly distributed along the equatorial margin (of the cingulum) and on the distal hemisphere. Exine otherwise laevigate or occasionally densely infrapunctate or infragranulate on the body.

Dimensions: (16 specimens) Overall diameter (including projections) 44-67 μ (mean 56 μ), body diameter 31-48 μ (mean 37 μ).

Holotype: Preparation M928/2, 46.4 104.7 Dialux 1.

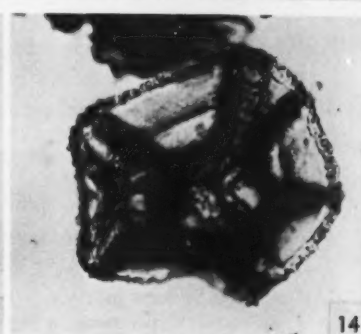
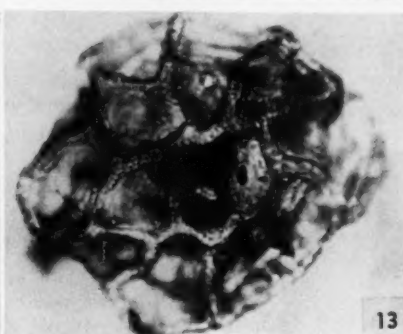
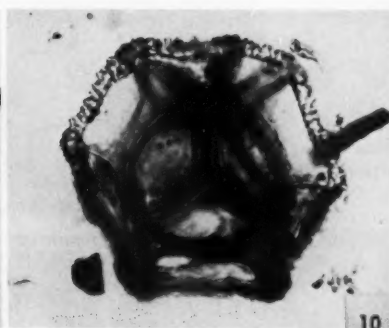
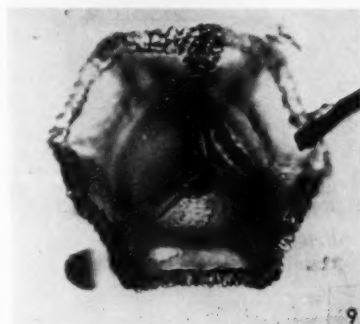
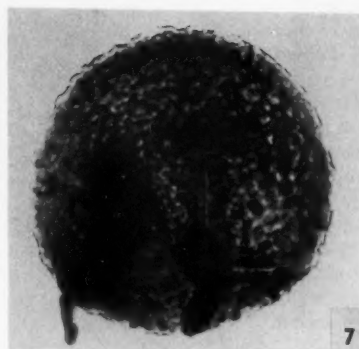
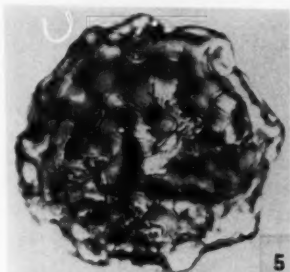
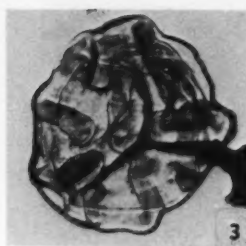
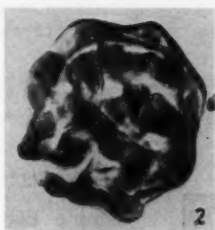
Locus typicus: Sample B685, Lower Carboniferous, Spitsbergen.

Description: Holotype diameter 56 μ . The type of projection is constant in any one specimen, but may range from baculae to verrucae which may be fused longitudinally in groups of from two to five.

PLATE 1

All figures $\times 500$, and from unretouched negatives.

- 1 *Leiotriletes inermis* (Waltz) Potonié and Kremp
Proximal view; preparation M949/1, 34.1 99.6.
- 2 *Convolutispora vermiformis* sp. nov.
Holotype; proximal view.
- 3 *Convolutispora vermiformis* sp. nov.
Proximal view; preparation M928/1, 25.2 114.1.
- 4 *Convolutispora vermiformis* sp. nov.
Proximal view; preparation M811/1, 56.7 97.6.
- 5 *Reticulatisporites planus* sp. nov.
Distal view; preparation M928/2, 47.6 96.8.
- 6 *Reticulatisporites planus* sp. nov.
Holotype; proximal view.
- 7 *Convolutispora clavata* (Ishchenko) comb. nov.
Proximal view; preparation P150/3, 41.2 107.7.
- 8 *Convolutispora clavata* (Ishchenko) comb. nov.
Proximo-lateral view; preparation P150/3, 45.2 94.3.
- 9-11 *Knoxisporites margarethae* sp. nov.
Holotype; proximal view: 9, high focus; 10, central focus; 11, low focus. (Diagrammatically represented in text-figure 2.)
- 12 *Knoxisporites margarethae* sp. nov.
Proximal view; preparation M928/2, 26.1 97.2.
- 13 *Knoxisporites margarethae* sp. nov.
Distal view; preparation M928/2, 25.9 96.1.
- 14 *Knoxisporites margarethae* sp. nov.
Distal view (low focus); preparation M928/1, 26.4 106.0.



Comparison: *Lophozonotriletes excisus* Naumova 1953, pl. 11, fig. 18, is constantly smaller (30–40 μ) and the projections appear to be on the proximal face, as implied also by Potonié (1958). Type 45 of Reinsch (1884, p. 5, pl. 9, fig. 117) has regular projections and a shorter trilete.

Infraturma PATINATI Butterworth and Williams, 1958

Genus THOLISPORITES Butterworth & Williams, 1958

Tholisporites foveolatus Hughes and Playford,
new species

Plate 4, figures 1–7

Diagnosis: Spores radial, trilete; amb convexly subtriangular, entire to slightly irregular; well-defined, proximal, thin-walled central area; thickened patina constituting wide equatorial zone and whole distal hemisphere. Laesurae slightly elevated, straight to sinuous, extending onto equatorial zone. Proximal area roundly triangular to subcircular, infragranulate to sparsely granulate. Close to the inner margin of the equatorial zone (proximal view) is a single thickened ring of closely compacted, radially elongated pyriform pits; sculpture of remainder of zone consists of sparsely and irregularly arranged pits, small warts, spines or grana usually with a tendency to radial elongation.

Whole distal surface with granulate, obervermiculate or microreticulate sculpture which decreases equatorially as the zone thins.

Dimensions: (25 specimens) Overall equatorial diameter 52–77 μ (mean 62 μ), diameter of central area 24–36 μ (mean 31 μ).

Holotype: Preparation M928/2, 51.5 101.8 Dialux 1.

Locus typicus: Sample B685, Lower Carboniferous, Spitsbergen.

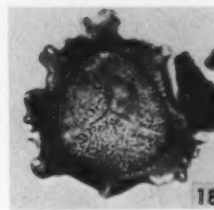
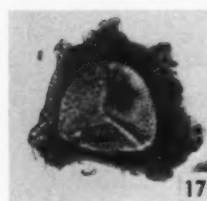
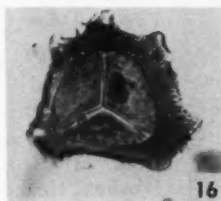
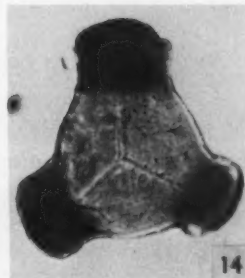
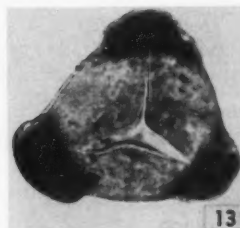
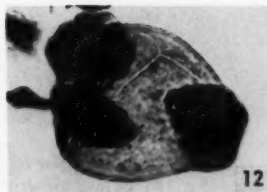
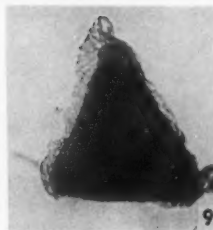
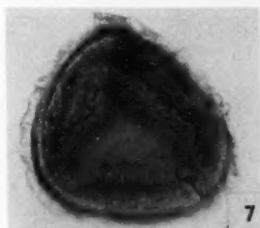
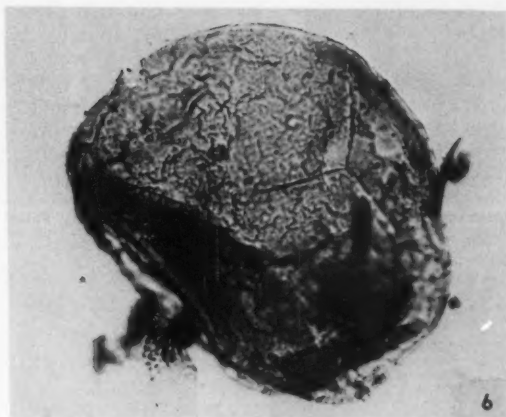
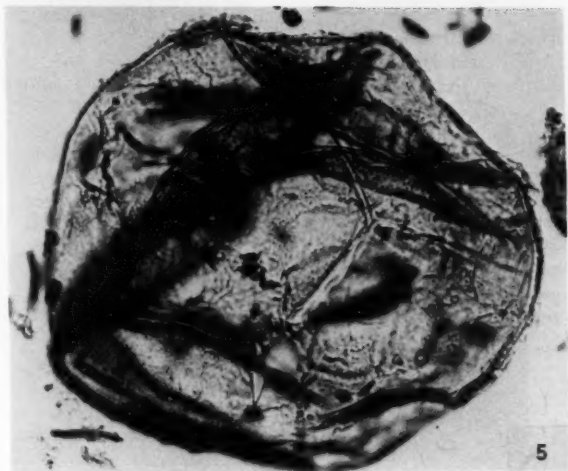
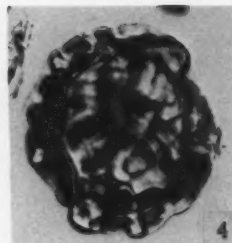
Description: Holotype 58 μ ; central area of diameter 25 μ , very thin, finely granulate, tumid; laesurae slightly elevated and sinuous, length 5/6 amb radius; pyriform pits 7–9 μ long, up to 2 μ wide, closely compacted on proximal inner margin of patina to form prominent ring enclosing central area; remainder of patina with irregularly and sparsely distributed pits and grana. Proximal central area being thin and delicate is frequently lost in poorly preserved specimens, and is seldom visible in distal view.

Comparison: Differs from *Densosporites variabilis* (Waltz) Potonié and Kremp, 1955, in being patinate and in having a smaller central area and longer laesurae. It resembles some of the figures of *Vallatisporites* Hacquebard, 1957, but the "patina" does not agree with his description.

PLATE 2

All figures \times 500, and from unretouched negatives.

- 1 *Knoxisporites cinctus* (Waltz) Butterworth and Williams
Distal view (low focus); preparation M811/3, 33.6 102.3.
- 2 *Knoxisporites cinctus* (Waltz) Butterworth and Williams
Distal view; preparation M949/5, 32.3 106.4.
- 3–4 *Knoxisporites cinctus* (Waltz) Butterworth and Williams
Proximal view: 3, high focus; 4, low focus; preparation M811/2, 42 94.8.
- 5 *Perotrilites magnus* sp. nov.
Holotype; proximal view.
- 6 *Perotrilites magnus* sp. nov.
Proximal view; preparation M811/2, 56.4 102.4.
- 7 *Perotrilites perinatus* sp. nov.
Holotype; proximal view (laesurae not in focus).
- 8 *Perotrilites perinatus* sp. nov.
Proximal view; preparation M811/5, 45.8 114.5.
- 9 *Perotrilites perinatus* sp. nov.
Proximal view; preparation M811/2, 42.5 96.5.
- 10 *Perotrilites perinatus* sp. nov.
Distal view; preparation M928/2, 31.1 97.3.
- 11 *Triquitrites batillatus* sp. nov.
Holotype; proximal view.
- 12 *Triquitrites batillatus* sp. nov.
Lateral view; preparation P150/3, 48.9 104.2.
- 13 *Triquitrites batillatus* sp. nov.
Proximal view; preparation P150/1, 30.5 113.3.
- 14 *Triquitrites batillatus* sp. nov.
Proximal view; preparation P150/2, 23.7 92.3.
- 15 *Tripartites incisorilobus* (Naumova) Potonié and Kremp
Proximal view; preparation M811/4, 43.8 98.7.
- 16–17 *Densosporites striatiferus* sp. nov.
Holotype; proximal view; 16, high focus; 17, low focus.
- 18 *Densosporites striatiferus* sp. nov.
Proximal view; preparation M811/3, 32.0 98.3.



Infraturma ZONATI Potonié and Kremp, 1954
Genus DIATOMOZONOTRILETES (Naumova) Potonié and Kremp, 1956

Diatomozonotriletes saetosus (Hacquebard and Barss), new combination
Plate 4, figures 14–15

Zonotriletes speciosus, non Loose sp., Waltz, 1938

Diatomozonotriletes speciosus, non Loose sp., Ishchenko, 1956

Reinschospira saetosus Hacquebard and Barss, 1957

Description of specimens: Spores radial, trilete; amb sub-triangular with concave sides (often markedly so) and rounded to truncated apices. Laesurae straight, perceptible to distinct, extending almost to triangular apices. Equatorial "flange" consisting of 9–15 discrete, more or less pointed setae projecting laterally from each interrational margin. Setae 3–20 μ long (longest in central interrational areas), 2.5–5 μ wide at base, absent at triangular apices. Exine thick (2.5–4 μ), laevigate.

Dimensions: (14 specimens) Diameter (excluding setae) 45–63 μ (mean 54 μ).

Comparison: The specimens conform in most respects to the description given by Hacquebard and Barss (1957),

except that the amb is often more strongly concave and the setae are often considerably longer than the stated 3–11 μ . *Diatomozonotriletes saetosus* includes spores incorrectly assigned to Loose's species, i.e., *R. speciosa* (Loose) Schopf, Wilson and Bentall, by Waltz (in Lubert and Waltz, 1938) and subsequently by Ishchenko (1956, 1958).

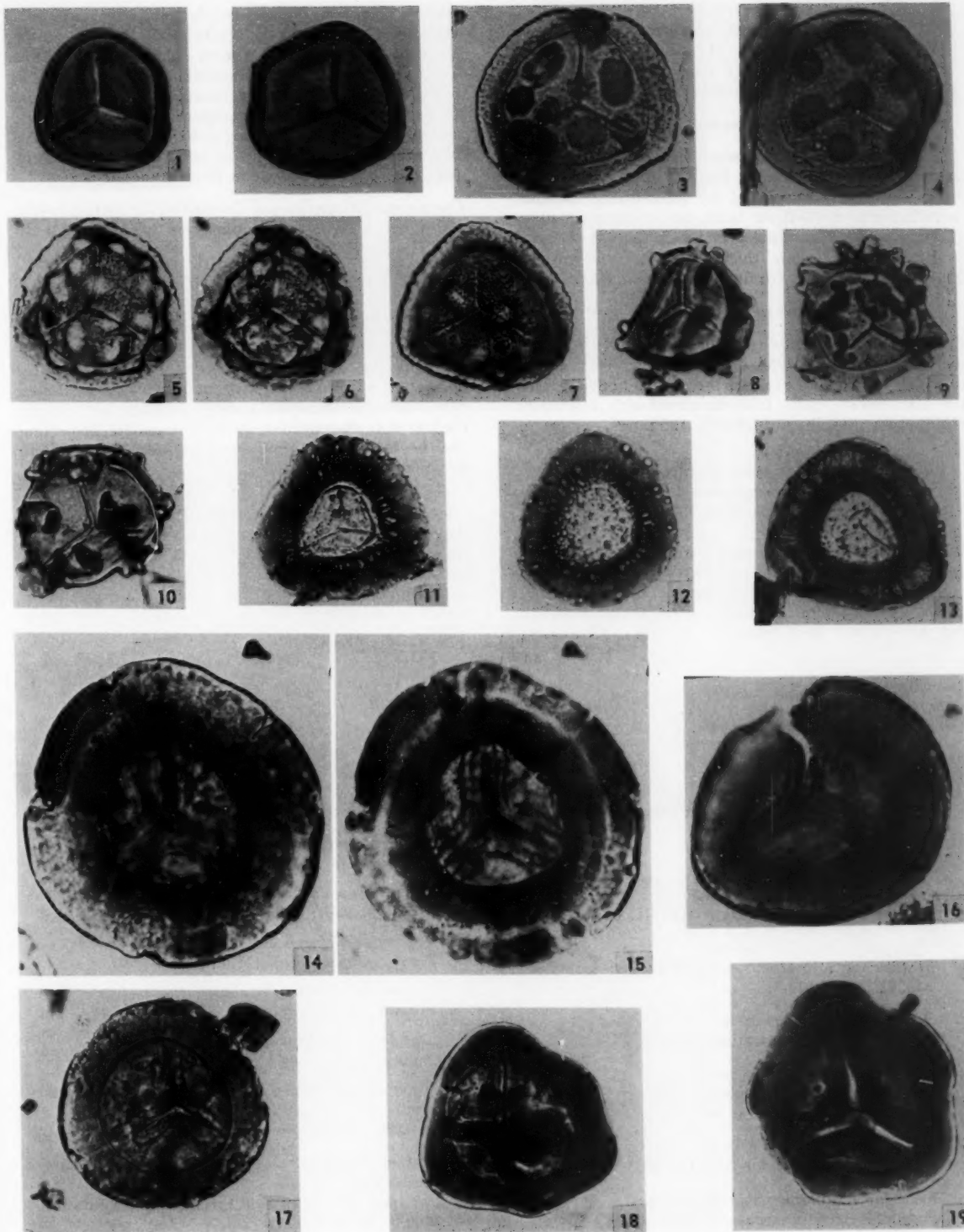
Occurrence: Sample B609, Lower Carboniferous, Spitsbergen. Also from Lower Carboniferous of Moscow and Kizel Basins (Lubert and Waltz 1938); lower Viséan only of Western Donetz Basin (Ishchenko, 1956); Viséan-Namuria of Dnieper-Donetz Basin (Ishchenko, 1958); and Lower Carboniferous (probable Viséan) of south Nahanni River area, Northwest Territories, Canada (Hacquebard and Barss, 1957).

Discussion: The genus *Diatomozonotriletes* as emended by Potonié and Kremp is used for these distinct Lower Carboniferous spores in preference to a somewhat confused sectional subdivision of *Reinschospira* advocated in Potonié and Kremp (1956a, p. 132); Potonié (1956, p. 69) discusses this matter but, by his arrangement, gives generic (and not subgeneric) rank to *Diatomozonotriletes*.

PLATE 3

All figures $\times 500$, and from unretouched negatives.

- 1 *Stenozonotriletes clarus* Ishchenko
Proximal view; preparation M811/3, 38.9 112.6.
- 2 *Stenozonotriletes clarus* Ishchenko
Proximal view; preparation M811/1, 46.6 96.5.
- 3 *Lophozonotriletes triangulatus* sp. nov.
Distal view; preparation M928/1, 26.4 93.4.
- 4 *Lophozonotriletes triangulatus* sp. nov.
Proximal view; preparation M811/1, 61.2 101.9.
- 5–6 *Lophozonotriletes triangulatus* sp. nov.
Proximal view: 5, high focus; 6, low focus;
preparation M928/1, 49.5 109.8.
- 7 *Lophozonotriletes triangulatus* sp. nov.
Proximal view; preparation M928/2, 27.5 106.1.
- 8 *Lophozonotriletes dentatus* sp. nov.
Proximal view; preparation M811/4, 51.8 94.2.
- 9 *Lophozonotriletes dentatus* sp. nov.
Distal view; preparation M949/4, 41.6 103.2.
- 10 *Lophozonotriletes dentatus* sp. nov.
Holotype; distal view.
- 11 *Densosporites variabilis* (Waltz) Potonié and Kremp
Proximal view; preparation M883/1, 31.4 109.
- 12 *Densosporites variabilis* (Waltz) Potonié and Kremp
Distal view; preparation M883/1, 31.8 111.2.
- 13 *Densosporites variabilis* (Waltz) Potonié and Kremp
Proximal view; preparation M883/1, 30.2 101.2.
- 14–15 *Anulatisporites labiatus* sp. nov.
Holotype, distal view: 14, high focus; 15, low focus.
- 16 *Anulatisporites labiatus* sp. nov.
Proximal view; preparation M928/3, 32.3 101.1.
- 17 *Anulatisporites labiatus* sp. nov.
Proximal view; preparation M928/2, 37.8 99.7.
- 18 *Cincturasporites literatus* (Waltz) Hacquebard and Barss
Proximal view; preparation P150/4 35.7 108.2.
- 19 *Cincturasporites auritus* (Waltz) Hacquebard and Barss
Proximal view; preparation P150/2, 34.1 94.3.



HUGHES AND PLAYFORD

Anteturma POLLENITES R. Potonić, 1931

Turma SACCITES Erdtman, 1947

Subturma MONOSACCITES (Chitaley) Potonić and Kremp, 1954

Infraturma EXTRORNATI Butterworth and Williams, 1958

Genus **Velosporites** Hughes and Playford, new genus

Diagnosis: Spores large, monosaccate, radial, trilete; amb irregularly subcircular. Distinct subcircular central body completely enveloped by loose-fitting bladder, with laesurae present on both, but continuing equatorially on bladder almost to reach margin. Central body dense, relatively thick-walled and sculptured. Bladder thin-walled with fine external sculpture.

Type species: *Velosporites echinatus* sp. nov.

Comparison: This genus resembles *Remysporites* Butterworth and Williams, 1958, differing chiefly in the extent to which the bladder encloses the central body. It lacks the characteristic radial folds associated with *Auroraspora* Hoffmeister, Staplin and Malloy, 1955.

Velosporites echinatus Hughes and Playford,
new species

Plate 4, figures 9–12

Diagnosis: Spores radial, trilete; amb irregularly subcircular, entire to undulating; central body completely enveloped by loosely fitting bladder. Laesurae conspicuously present on both central body and bladder. On the bladder they constitute elevated, frequently

folded ridges 5–8 μ high, up to 18 μ wide, almost attaining equatorial margin; on the central body they are simple, straight, narrow, length almost equal to body radius. Central body circular to subcircular, sometimes coarsely folded, finely and sparsely echinate, coat relatively thick (1–3 μ). Bladder thin, transparent, frequently and irregularly folded, projecting a maximum of about 20 μ beyond equatorial margin of central body, sculpture (external) microreticulate or finely punctate.

Dimensions: (26 specimens) Overall equatorial diameter, 105–176 μ (mean 127 μ), diameter of central body 70–121 μ (mean 97 μ).

Holotype: Preparation M928/1, 58.8 103.6 Dialux 1.

Locus typicus: Sample B685, Lower Carboniferous Spitsbergen.

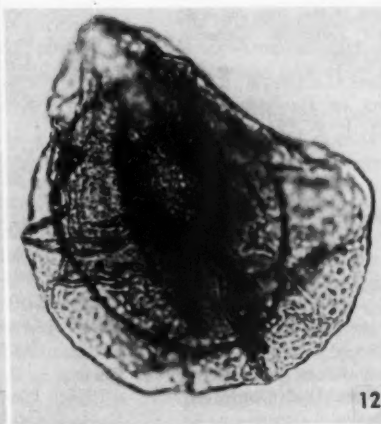
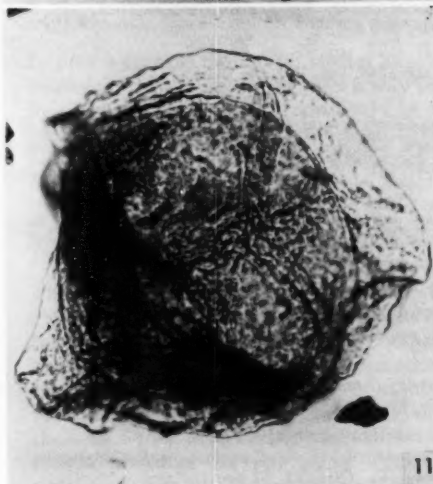
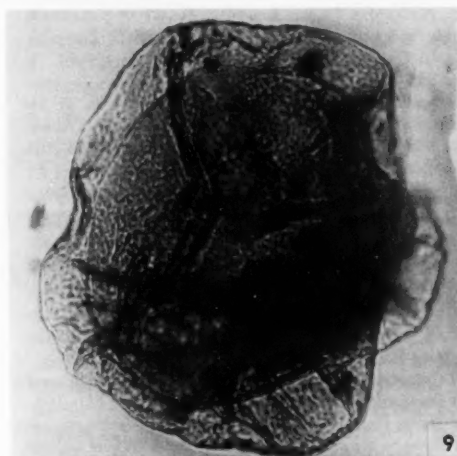
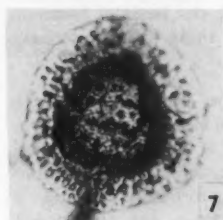
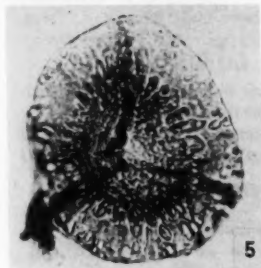
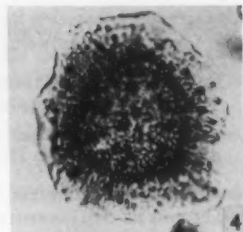
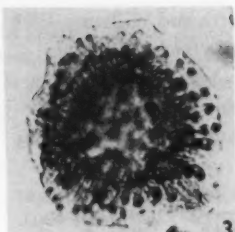
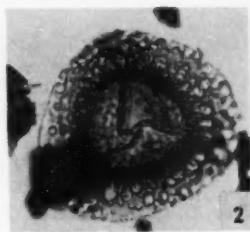
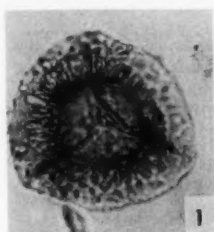
Description: Holotype 136 μ overall diameter; central body 104 μ , coat 1 μ thick, with small sparsely distributed coni; laesurae straight, narrow, almost to margin; bladder thin, discontinuously microreticulate, projecting 18 μ beyond central body, raised laesurae 5 μ high, 7 μ wide.

Comparison: This species resembles *Remysporites magnificus* (Horst) Butterworth and Williams, 1958, but differs in arrangement of bladder (see above) and in body wall sculpture. *Endosporites macromanifestus* Hacquebard, 1957, has a thin body wall but from its description should be placed in the Extrornati, and presumably in another genus.

PLATE 4

All figures $\times 500$, and from unretouched negatives.

- | | |
|---|---|
| <p>1 <i>Tholisporites foveolatus</i> sp. nov.
Holotype; proximal view.</p> <p>2 <i>Tholisporites foveolatus</i> sp. nov.
Proximal view; preparation M811/1, 35.0 104.7.</p> <p>3–4 <i>Tholisporites foveolatus</i> sp. nov.
Distal view: 3, low focus; 4, high focus; preparation M928/3, 47.5 103.3.</p> <p>5 <i>Tholisporites foveolatus</i> sp. nov.
Proximal view; preparation M928/3, 24.9 93.4.</p> <p>6 <i>Tholisporites foveolatus</i> sp. nov.
Proximal view of specimen lacking proximal central area; preparation M811/4, 56.6 93.9.</p> <p>7 <i>Tholisporites foveolatus</i> sp. nov.
Distal view; preparation M811/3, 40.1 94.0.</p> <p>8 <i>Endosporites micromanifestus</i> Hacquebard.
Proximal view; preparation M811/2, 49.5 100.1.</p> | <p>9 <i>Velosporites echinatus</i> gen. et sp. nov.
Holotype; proximal view.</p> <p>10 <i>Velosporites echinatus</i> gen. et sp. nov.
Proximal view; preparation M928/1, 49.5 109.8.</p> <p>11 <i>Velosporites echinatus</i> gen. et sp. nov.
Proximal view; preparation M811/4, 30.9 98.</p> <p>12 <i>Velosporites echinatus</i> gen. et sp. nov.
Proximal view; preparation M949/7, 48.1 102.6.</p> <p>13 <i>Lophotriletes coniferus</i> sp. nov.
Holotype; proximal view.</p> <p>14 <i>Diatomozonotriletes saetosus</i> (Hacquebard and Barss) comb. nov.
Proximal view; preparation M803/2, 60.0 95.0.</p> <p>15 <i>Diatomozonotriletes saetosus</i> (Hacquebard and Barss) comb. nov.
Proximal view (broken specimen); preparation M803/2, 39.3 110.3.</p> |
|---|---|



Infraturma INTRORNIATI Butterworth and Williams, 1958
Genus ENDOSPORITES Wilson and Coe, 1940

Endosporites micromanifestus Hacquebard
Plate 4, figure 8

Hymenozonotriletes aff. *variabilis* Naumova. Ishchenko, 1956,
p. 62, pl. 9, figs. 129, 130.

Dimensions: (12 specimens) Overall equatorial diameter 44–80 μ (mean 61 μ), central body 29–52 μ (mean 40 μ). These measurements are a little lower than the size ranges quoted by Hacquebard on the basis of fourteen specimens, but in other respects these grains conform closely to his description.

Discussion: Hacquebard notes the similarity between this species and *Hymenozonotriletes variabilis* Naumova, 1953, which differs in possessing a circular equatorial outline. However, the spores recorded by Ishchenko (1956) as *Hymenozonotriletes* aff. *variabilis*, having a roundly triangular equatorial outline, are considered referable to *E. micromanifestus*.

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ABSTRACT Recent living, dead and total foraminiferal populations in sediment samples collected by aqualung divers in the vicinity of Heald Bank, northwest Gulf of Mexico were studied. Fifty living species were identified; living specimens composed thirty-five percent of the total fauna. Comparisons of living, dead and total populations permit valid ecological conclusions and suggest geological considerations on changing conditions and transportation of tests. Faunal variations within short lateral distances are appreciable.

Living, dead, and total foraminiferal faunas, Heald Bank, Gulf of Mexico

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EDITOR'S NOTE: It is the sad task of *The Editors* to report that Miss Shifflett died while this paper was in press.

INTRODUCTION

Many papers on Recent foraminifera, which have appeared during the past decade, emphasize the ecology of genera and species. In the majority of these studies two basic assumptions are made. The first assumption frequently made is that a total population (living plus dead, undifferentiated) recovered from a sample is representative of the living population at that sample locality. This may lead to erroneous ecological conclusions regarding the relationships between foraminiferal distributions and environmental factors. Further, interpretations bearing on transportation of shells, changing conditions, relic populations and new population elements may be overlooked. The second assumption is that a sample of a small cross sectional area (whether it be a grab sample or a small diameter core) is representative of a large area on the sea floor.

In only a meager number of studies have samples been treated in the laboratory in such a way that specimens living at the time of collection could be differentiated from empty tests. Several studies provide information on living foraminiferal populations in the Gulf of Mexico, the Mississippi Delta area and in bays along the Texas coast (Phleger, 1951, 1955, 1956; Phleger and Lankford, 1957; Parker, 1954; Ludwick and Walton, 1957; Lankford, 1959).

This paper is presented to emphasize three points: (1) the study of living populations is the most desirable basis for ecological conclusions, (2) comparison of living and dead populations can yield information on changing conditions and on the processes of transportation and concentration which affect the final entombment of shells in a rock unit, and (3) faunal variations in short lateral distances are apt to be appreciable and in detailed studies must be compensated by close sampling.

For purposes of discussion the results of a study of living, dead and total foraminiferal populations in twelve shallow-water samples collected by aqualung divers from four localities in the Gulf of Mexico are presented.

COLLECTION OF SAMPLES AND METHODS OF STUDY

Since 1952, a program of research on Recent sediments from the Gulf of Mexico has been in progress at the Field Research Laboratory of the Socony Mobil Oil Company. The area studied is approximately 1,000 square miles in size. It is bounded by Sabine Pass and High Island on the northeast Texas coast and extends some thirty miles out to sea. An extensive study of Recent shallow-water foraminifera in more than 600 samples from depths of less than ten fathoms was based on total foraminiferal populations recovered from the top two inches of sediment with no differentiation between living and dead specimens. As the study was ecological in nature, it was necessary to establish the fact that these total populations actually represent living populations. Otherwise, conclusions drawn regarding the relationships between foraminiferal species and environmental factors, such as depth and salinity of water and type of sediment, would be open to question.

In a preliminary effort to ascertain how well the total foraminiferal populations represent living populations, samples were collected from ten localities in the vicinity of Heald Bank (text-figure 1) and preserved in alcohol for the study of the living populations. In the laboratory the samples were washed on silk screens, stained with Rose Bengal solution and examined while wet according to the method described by Walton (1952).

Four localities were sampled by geologists during aqualung dives to examine the sea floor. At each locality three samples were taken within a radius of approximately 100 feet for a study of the long-recognized problem of interpreting conditions over a large area of the sea

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Some fifty species which occur only rarely in the total population have not been found living. Comprehensive sampling would undoubtedly reveal living specimens of many of these species. In deeper waters (mainly 20–200 meters) in the northwest Gulf of Mexico, Phleger (1951) recorded living populations in more than 200 samples and reported living specimens of seventy-eight benthonic species, about 40 percent of the total number of species identified in the samples. In a study of calcareous prominences at the edge of the continental shelf in the northeastern Gulf of Mexico, Ludwick and Walton (1957, p. 2082) reported 150 benthonic species of which all but 44 were found living.

Percent of living specimens

In the twelve dive samples living specimens composed approximately 35 percent of the foraminiferal fauna; i.e., of 2217 specimens counted, 788 were identified as living. In individual samples, the living population composed from 7 to 53 percent of the total population. This may be considered a good recovery of living populations. In three Texas bays, Phleger (1956, p. 111) found living specimens composing from less than 1 to 15 percent of the total population. The living population of continental shelf faunas off the central Texas coast composes from less than 1 to 25 percent, according to the same study by Phleger. The lower percentages were found on the more southern traverses of Phleger's study and the higher percentages on traverses farther north, off San Antonio Bay. Lankford (1959, p. 2092) reported that the living population composed from 25 percent to more than 90 percent of the total population in the deltaic marine environment of the east Mississippi Delta and decreased offshore to less than 10 percent and frequently to less than one percent in open Gulf samples.

Living, dead and total populations

In studying Recent faunas, the problem of how well the total population (living plus dead) reflects the composition of the living population must be investigated. In areas of high productivity where there is a large percentage of living organisms the total population will be greatly affected by the census of living animals. In such a case the total population is a good representation of the living population, and ecological conclusions drawn from detailed total population studies are valid. In areas where few animals are living the total census will be composed mainly of the accumulated shells of dead organisms. In such a case, the total population may not be a good representation of the living population, and ecological conclusions may be unsafe, but comparison of living and dead elements of the same assemblage may yield useful information on past environmental changes or transportation of tests.

Comparisons of living, dead and total populations can be fruitful in two ways: (1) ecological conclusions drawn from total population studies can be validated by showing that total populations are representative of

living populations; (2) environmental changes or post-mortem transportation of tests may be indicated by quantitative studies which reveal new population elements, species which are found to be much more abundant in actual numbers in the live population than in the dead, and relic faunas, species which are found in great abundance in the dead population but are absent or found only in small percentages in the living census.

For purposes of comparing the living, dead and total populations at each of the four Heald Bank dive localities, the specimen counts of the three samples from each site have been totaled to give a composite picture of the fauna at each locality.

Text-figure 2 illustrates the first application of item (1) mentioned above. The locality (56071804) yielded a living population which constituted approximately 45 percent of the total population. Thirty-four species were identified of which 27 are represented by living specimens, 22 by both living and dead specimens. It is apparent that the total population represents very well the relative frequencies of the various species in the actual living population. Ecological conclusions regarding environmental effects based only on the total population would be quite safe in this case. However, some information would be missed which a comparison of the living and dead populations reveals. *Elphidium poeyanum* is noticeably more abundant in the living population than in the dead, suggesting that the colony of this species now flourishing at this locality has been introduced here rather recently. *Hanzawaia strattoni* is also represented by about twice as many living specimens as dead ones.

At another locality (56073102, not illustrated) the relative frequencies of species in the living, dead and total populations, on the whole, also correspond well, although not so closely as at the previous locality. The living population comprised 34 percent of the total census. Of 42 species observed, 25 were represented by living specimens, and 21 were recorded both living and dead. Each species which was not observed living comprised less than 2 percent of the total population. One species, *Nodobacularella cassis*, may be a new population element. More than twice as many specimens of this species were found living than dead. Many more empty tests should be present in the dead population if this form had been thriving here for a long time.

Text-figure 3 illustrates the second application of comparing living and dead populations over the same area of the sea floor, that of revealing clues concerning post mortem transportation of shells and environmental changes. The locality illustrated (56072801) yielded about 17 percent living specimens. Of 25 species, 14 were observed living, and 12 were observed both living and dead. In the living population *Elphidium* is prominent, composing 40 percent of the population. *Asterigerina carinata* is probably a new population element. It composes 15 percent of the living fauna and only 1 percent of the dead. A striking discrepancy

between the living and dead populations of miliolids (*Triloculina*, *Quinqueloculina*, *Massilina*, *Pyrgo*) exists here. A dozen species belonging to the miliolid group compose almost 75 percent of the dead population but only 16 percent of the living population. One form which obviously is not living in this locality in any abundance is *Massilina peruviana*. Ninety-two empty tests of this species were found and only two living specimens. Two explanations may be invoked to account for this anomaly.

(1) Conditions may have changed at this spot so that the miliolids are no longer thriving. A deepening of the water with the transgression during the Recent might provide such a change. With this explanation it must be postulated that at least several thousand years were required for the accumulation of the centimeter or so of sediment obtained in the sample. Ludwick and Walton (1957, p. 2088) cite foraminiferal species which occur in large concentrations in the dead population but sparsely or not at all in the living population in an area of reeflike features near the edge of the continental shelf in the Gulf of Mexico. Sedimentary and faunal characteristics indicate these features "flourished under previous environmental conditions of shallower, possibly warmer waters" (op. cit., p. 2054). (2) Post mortem concentration of the miliolid tests may have been effected by currents which transported and dropped them at this locality. In this particular sample it appears quite plausible that the empty miliolid tests have been transported to this position and deposited in a sandy shell sediment on the perimeter of a shell bank where miliolids are known to occur more abundantly. This idea is supported by the fact that the glauconite and terrigenous sand which are in the same size range as the foraminifera show evidence of sorting and concentration into the shelly sands bordering the shell banks in the area. The smaller median diameter of these components in the sandy shell debris indicates winnowing action of currents which have carried material out of the shell debris and concentrated it in the surrounding area. An alternative interpretation involving concentration but not transportation of the miliolids is furnished by another consideration. The relatively large size of *Massilina peruviana* and of many of the miliolids in the adult stage suggests concentration in situ of the miliolid population by winnowing out of the smaller tests of other foraminifera. In any problem all pieces of evidence must be brought to bear on the solution. The object here is not a definite conclusion regarding this particular sample site but to show that a comparison of the living and dead populations in an area, properly evaluated, can conceivably yield geological information regarding changing conditions or post mortem concentration and transportation of shells.

At the last remaining dive locality (56073101, not illustrated) the living population comprised 37 percent of the total population. Nineteen out of 26 species were observed living, and 17 were observed both living and dead. *Elphidium* spp. composed almost half of the living population, and *Hanzawaia strattoni* and *Asterigerina carinata* were more abundant elements in the living

than in the dead populations. A fairly large discrepancy in the living and dead miliolid occurrences exists here. This group composed approximately 50 percent of the dead population and only 7 percent of the living population. Thus there is again the suggestion of transportation and concentration of these tests by sorting action or of accumulation in situ of old populations.

In the latter two localities total population studies would not furnish an entirely sound basis for ecological conclusions regarding the relationship of species to environmental factors. The total census of the miliolids is largely a reflection of the dead population, and correlations drawn between their occurrence and any physical properties of the local environment at the present time would very possibly be erroneous. With the exception of these miliolid accumulations, the relative frequencies of the major groups of foraminifera in the living and total populations correspond well in the samples studied.

FAUNAL VARIATIONS IN SHORT LATERAL DISTANCES

A problem which has long existed is the necessity for interpreting conditions over a large area of the sea floor on the basis of a sample of small cross sectional area. The same problem exists in the construction of the geologic history of rock units in a region from the study of cores. Geologists and paleontologists have seldom concerned themselves to any great degree with the problem of the tremendous variability of many natural properties within short distances. At each of the four dive localities three samples were collected within a radius of approximately 100 feet to allow a study of the faunal variations. Tables 1 through 4 record the pertinent results of the variability studies.

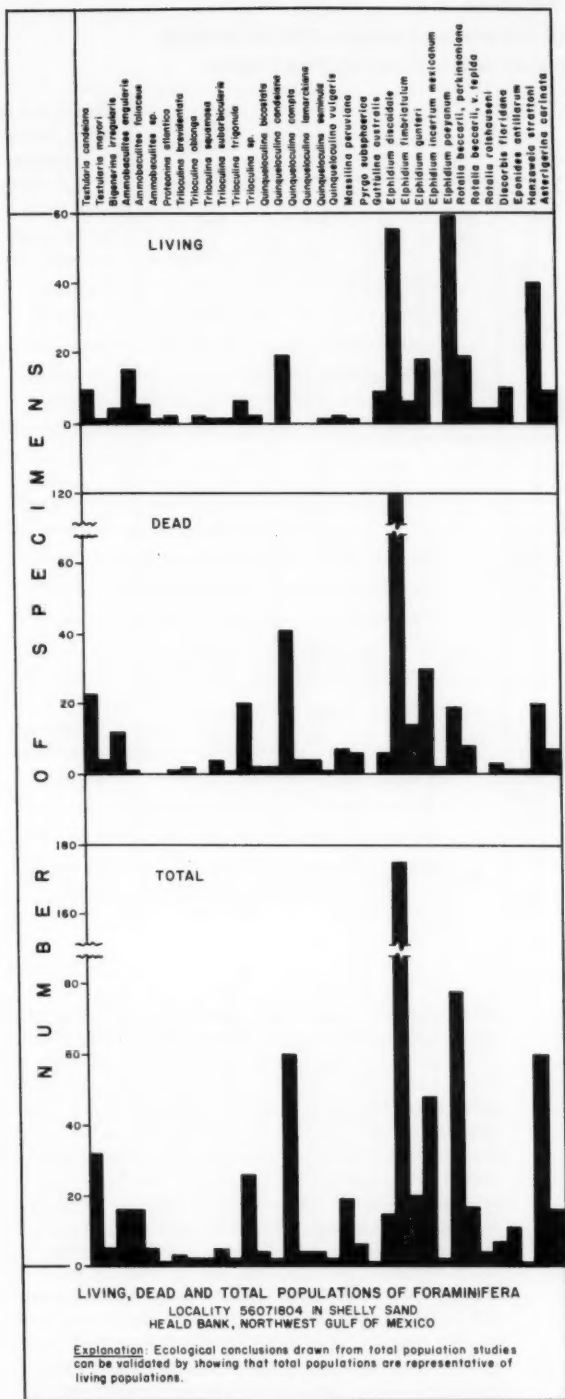
SAMPLE TO SAMPLE VARIATION

1) *Total number of species*: A maximum variation of ten species was observed at locality 56073102 where the number of species in three closely spaced samples was 22, 28 and 32 respectively (Table 1). At the three other dive localities the number of species in three samples per locality corresponded well and varied by only three species at each locality (Tables 2-4).

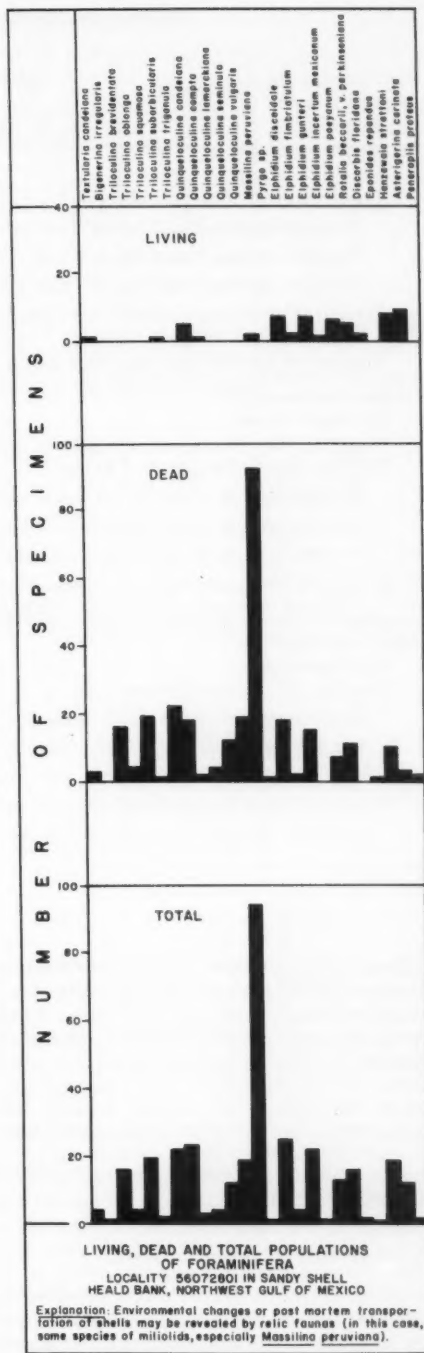
2) *Living species*: A maximum variation of ten species was observed at locality 56071804 where the number of species observed living in three closely spaced samples was 13, 19 and 23 respectively (Table 3). Variations in three closely-spaced samples at other localities were as follows: locality 56073102 - eight species; locality 56072801 - six species; locality 56073101 - two species (Tables 1, 2, 4).

3) *Dead species*: A maximum variation of eleven species was observed at locality 56073102 where the number of species observed dead in three closely spaced samples was 19, 27 and 30 respectively (Table 1). Variations in three closely spaced samples at other localities were as follows: locality 56073101 - five species; locality 56071804 - three species; locality 56072801 - two species (Tables 4, 3, 2).

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TEXT-FIGURE 2



TEXT-FIGURE 3

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TABLE 1

VARIABILITY OF LIVING, DEAD AND TOTAL FORAMINIFERAL SPECIES IN THREE
CLOSELY SPACED SAMPLES, DIVE LOCALITY 56073102, HEALD BANK

	Samples			Whole locality	Maximum variation between samples
	A	B	C		
TOTAL POPULATION					
Specimen count	89	259	174	522	
Total number of species observed	22	28	32	42	10
Number species found in all three samples	16				
Number species found in only two samples	12				
Number species found in only one sample	14				
Percent of total population composed of species common to all three samples	84%	69%	79%	75%	
Number of species observed both living and dead	6	12	13	21	7
LIVING POPULATION					
Specimen count	20	91	66	177	
Percent living specimens in total fauna	23%	35%	38%	34%	15%
Number of species observed living	9	17	15	25	8
Number species found in all three samples	4				
Number species found in only two samples	8				
Number species found in only one sample	13				
Percent of living population composed of living species common to all three samples	65%	56%	38%	50%	27%
DEAD POPULATION					
Specimen count	69	168	108	345	
Number of species observed dead	19	27	30	38	11
Number species found in all three samples	15				
Number species found in only two samples	9				
Number species found in only one sample	14				
Percent of dead population composed of dead species common to all three samples	84%	65%	74%	72%	19%

4) *Percent living specimens in total fauna*: A maximum variation of 20 percent was observed at locality 56071804 where the living percentages in the total populations of three closely spaced samples were 33, 46 and 53 percent respectively (Table 3). Variations in three closely spaced samples at other localities were as follows: locality 56073102 - 15 percent; locality 56072801 - 19 percent; locality 56073101 - 12 percent (Tables 1, 2, 4).

Sample-to-sample variations of other properties are shown on the tables.

FAUNA AS REVEALED BY INDIVIDUAL SAMPLES

How well a single sample from a locality reflects the composition of the fauna in the vicinity of that locality is the important question, inasmuch as one sample per locality is what the geologist or paleontologist usually has to work with.

With regard to the total number of species, results of the present study suggest that a single sample may fail to show about one-fourth to one-half the total species from the locality. Table 1, for example, shows that 42 species were recorded for the whole locality; the three individual samples contained 22, 28 and 32 species respectively. The sample containing only 22 species fails to record almost half the species present in the immediate vicinity. Table 3 shows that a total of 34 species was recorded for the whole locality, but two of the individual samples contained only 24 species and one contained 27.

In the case of living and dead species in Recent sediment samples, indications are that one sample from a locality may fail to record about one-fourth of the species in either the living or dead populations. Table 3, for example, shows that 27 species were recorded living in the locality, but three individual samples contained only 13, 19 and 23 species living. In the dead population

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TABLE 2

VARIABILITY OF LIVING, DEAD AND TOTAL FORAMINIFERAL SPECIES IN THREE
CLOSELY SPACED SAMPLES, DIVE LOCALITY 56072801, HEALD BANK

	Samples			Whole locality	Maximum variation between samples
	A	B	C		
TOTAL POPULATION					
Specimen count	111	102	127	340	
Total number of species observed	20	20	17	25	3
Number species found in all three samples	13				
Number species found in only two samples	6				
Number species found in only one sample	6				
Percent of total population composed of species common to all three samples	88%	90%	95%	91%	
Number of species observed both living and dead	9	9	4	12	5
LIVING POPULATION					
Specimen count	23	26	8	57	
Percent living specimens in total fauna	21%	26%	7%	17%	19%
Number of species observed living	11	11	5	14	6
Number species found in all three samples	3				
Number species found in only two samples	7				
Number species found in only one sample	4				
Percent of living population composed of living species common to all three samples	39%	35%	75%	42%	40%
DEAD POPULATION					
Specimen count	88	76	119	283	
Number of species observed dead	18	18	16	23	2
Number species found in all three samples	12				
Number species found in only two samples	5				
Number species found in only one sample	6				
Percent of dead population composed of dead species common to all three samples	89%	89%	95%	91.5%	6%

at the same locality 29 species were recorded, but three individual samples contained 19, 21 and 22 dead species.

A very interesting aspect of faunal variations in samples from the same locality concerns the number of species which the samples have in common. This is shown on the tables for the living, dead and total populations. Table 1 shows that of 25 species identified as living in the whole locality, only four were found living in all three samples from that locality. Eight species were found living in two of the samples; an additional 13 species were found living in only one of the three samples. At the same locality 38 species were identified in the dead population. Fifteen of these were present in the dead populations of all three samples. Nine species were found in only two samples; an additional 14 species were identified in the dead population of only one of the three samples. At the same locality 42 species made up

the total population. Only 16 of the 42 species were found in all three samples from the locality. Twelve species were found in two of the samples, and an additional 14 species were found in only one of the three samples. The tables for the other three localities show variations of similar magnitude.

How well the living, dead and total assemblages of the dive localities are revealed by a single sample has been further evaluated by calculating the percentage of the populations composed of species common to all three samples at a locality. The living populations appear to be the most variable, and one sample from a locality may not give a true picture of the living assemblage of the immediate vicinity. Table 1 shows that, for the locality as a whole, 50 percent of the living population was composed of species found living in all three samples; in the three individual samples the percentages were 65, 56 and 38 percent. Therefore, 35 to 62 percent of

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TABLE 3

VARIABILITY OF LIVING, DEAD AND TOTAL FORAMINIFERAL SPECIES IN THREE
CLOSELY SPACED SAMPLES, DIVE LOCALITY 56071804, HEALD BANK

	Samples			Whole locality	Maximum variation between samples
	A	B	C		
TOTAL POPULATION					
Specimen count	222	202	237	661	
Total number of species observed	24	24	27	34	3
Number species found in all three samples	17				
Number species found in only two samples	7				
Number species found in only one sample	10				
Percent of total population composed of species common to all three samples	92%	92%	88%	91%	
Number of species observed both living and dead	16	11	15	22	5
LIVING POPULATION					
Specimen count	102	67	126	295	
Percent living specimens in total fauna	46%	33%	53%	45%	20%
Number of species observed living	19	13	23	27	10
Number species found in all three samples	12				
Number species found in only two samples	4				
Number species found in only one sample	11				
Percent of living population composed of living species common to all three samples	82%	98%	75%	83%	23%
DEAD POPULATION					
Specimen count	120	135	111	366	
Number of species observed dead	21	22	19	29	3
Number species found in all three samples	15				
Number species found in only two samples	3				
Number species found in only one sample	11				
Percent of dead population composed of dead species common to all three samples	93%	84%	95%	90%	11%

the living populations here were composed of species found in only one or two of the three samples. These could obviously be missed in only one sampling of the locality. Table 2 shows that, for the locality as a whole, only 42 percent of the living population was composed of species found living in all three samples; in the three individual samples the percentages were 39, 35 and 75 percent. Living populations were better represented by individual samples at the other two dive localities with more than 75 percent of the living populations composed of species found living in all three samples at each locality.

Results of this study indicate that one sample from a locality will probably give a better representation of the dead assemblage of the immediate vicinity than of the living assemblage. Table 1 shows that at this locality 72 percent of the dead population was composed of species found dead in all three samples; in the three individual samples, the percentages were 84, 65 and 74 percent. Species found in only one or two of the three

samples from the locality, therefore, composed 16 to 35 percent of the dead populations. At the other three dive localities more than 80 percent of the dead population in each sample was composed of species found in the dead populations of all three samples from the locality.

One sample from a locality will probably give a better representation of the total population (living plus dead) of the immediate vicinity than either the living or dead populations. Table 1 shows that 75 percent of the total population of the locality was composed of species common to all three samples; in the individual samples the percentages were 84, 69 and 79 percent. Therefore, 16 to 31 percent of the total population was composed of species found in only one or two of the three samples from the locality, and these species might be missed in only one sample. At the other three dive localities individual samples represented the total assemblage of the whole locality better than at the one just cited. In each of the nine samples involved 88 percent or more of

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TABLE 4

VARIABILITY OF LIVING, DEAD AND TOTAL FORAMINIFERAL SPECIES IN THREE CLOSELY SPACED SAMPLES, DIVE LOCALITY 56073101, HEALD BANK

	Samples			Whole locality	Maximum variation between samples
	A	B	C		
TOTAL POPULATION					
Specimen count	291	160	244	695	
Total number of species observed	19	20	22	26	3
Number species found in all three samples	15				
Number species found in only two samples	5				
Number species in only one sample	6				
Percent of total population composed of species common to all three samples	96%	91%	91%	93%	
Number of species observed both living and dead	13	9	12	17	4
LIVING POPULATION					
Specimen count	107	72	80	259	
Percent living specimens in total fauna	37%	45%	33%	37%	12%
Number of species observed living	13	15	13	19	2
Number species found in all three samples	9				
Number species found in only two samples	4				
Number species found in only one sample	6				
Percent of living population composed of living species common to all three samples	96%	88%	95%	93%	8%
DEAD POPULATION					
Specimen count	184	88	164	436	
Number of species observed dead	19	16	21	24	5
Number species found in all three samples	12				
Number species found in only two samples	8				
Number species found in only one sample	4				
Percent of dead population composed of dead species common to all three samples	87%	89%	81%	85%	8%

the total population was composed of species common to all three samples at each locality.

The present study shows that one sample from a locality may fail to record species which compose very appreciable percentages of the living, dead and total populations in the immediate vicinity. In the twelve samples studied, species which were *not* common to the three closely spaced samples at each locality composed up to 50 percent or more of the living population, up to 20 percent of the dead population and up to 10 or 15 percent of the total population in individual samples. These are, therefore, species which could easily be missed in one sampling of the locality.

The results discussed here emphasize the fact that organisms, and in this particular case foraminifera, live in colonies. A certain organism may live in abundance in a limited area and be rare or absent in an area only yards away. Sampling on the sea floor or in ancient rocks cannot, of course, be carried out on a grid so

closely spaced that the project becomes financially infeasible. However, the necessity for as large a quantity of samples as possible to obtain an adequate representation of faunas cannot be over emphasized. Further, a large number of samples does not obviate the need for taking the samples with the greatest possible care to assure their maximum reliability.

CONCLUSIONS

1) Fifty species of benthonic foraminifera have been identified living in the vicinity of Heald Bank, north-west Gulf of Mexico. They include all the species which are significant in the total population (living plus dead) of the area. About fifty species represented by rare occurrences in the total population have not been found living.

2) Living specimens composed thirty-five percent of the foraminiferal fauna in twelve samples recovered from the sea floor by aqualung divers. In comparison with

other studies this may be regarded as very good recovery of living populations.

3) Ecological conclusions regarding the relationship of organisms to the physical conditions of their environment can best be drawn from a study of living faunas. Ecological conclusions drawn from total population studies can be validated by showing that total populations are representative of living populations.

4) Comparisons of living, dead and total populations can be a key to paleoecology. Geological information of two types may be revealed by comparisons of living and dead populations. Changes in physical conditions such as depth, temperature and salinity may be reflected by the presence of relic faunas in the dead populations and of new population elements in the living fauna. Post-mortem transportation and redistribution of organisms, probably in the nature of a fanning out from centers of high productivity, can be detected by plotting separately the living and dead occurrences of species. Consideration of the possibilities of redistribution re-emphasizes the need for establishing the true ecological relationships between present-day organisms and their environments so that anomalous occurrences in the geologic column may be recognized and interpreted.

5) Living organisms are not uniformly distributed on the sea floor but appear to live in colonies. The variability of living, dead, and total populations within short lateral distances is appreciable and must always be a consideration in any problem. The main solution to the problem will be found in the study of adequate numbers of samples from an area.

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ABSTRACT *Thirteen species belonging to the ostracode genus Bairdia are divided into four groups based on differences and similarities in the morphology of the male copulatory organ. The effect of temperature, salinity, and substrate on the distribution of Bairdia is discussed. Four new species of Bairdia and one new species of Bairdoppilata collected in the Bahamas are described. The carapaces of females have smaller length-height ratios than those of males.*

Ecology and taxonomy of Recent Bairdiinae (Ostracoda)

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INTRODUCTION

Ostracodes have been extremely useful to geologists both for time-stratigraphic determination and depositional environment interpretation. In interpreting the paleoecology of fossil ostracodes, it is useful to know the environmental factors influencing the distribution of ostracodes now living. Of particular use is information concerning the distribution of living species whose ancestors have a long geologic record represented by an abundance of fossils. The genus *Bairdia* belongs in this category because it has a long range and is represented in the geologic record by an abundance of individuals and many species. Howe (1955, p. 13) estimated that at least 600 species of fossil and living ostracodes have been assigned to the genus *Bairdia*.

This study was made in the vicinity of the Bimini Islands, which are situated in the northwestern part of the Great Bahama Bank. The sample area covers approximately 320 square kilometers in the shallow waters east of the Bank rim (text-fig. 1). This paper is the third in a series describing Bahamian ostracodes. Previous papers are "Ecology and taxonomy of Recent marine ostracodes in the Bimini area, Great Bahama Bank" (Kornicker, 1958) and "Distribution of the ostracode suborder Cladocopa, and a new species from the Bahamas" (Kornicker, 1959). An ecological study in the Bahamian region becomes especially significant because the warm, clear shelf sea of this area may have similarities to limestone-forming seas which covered a large part of the continent in the past.

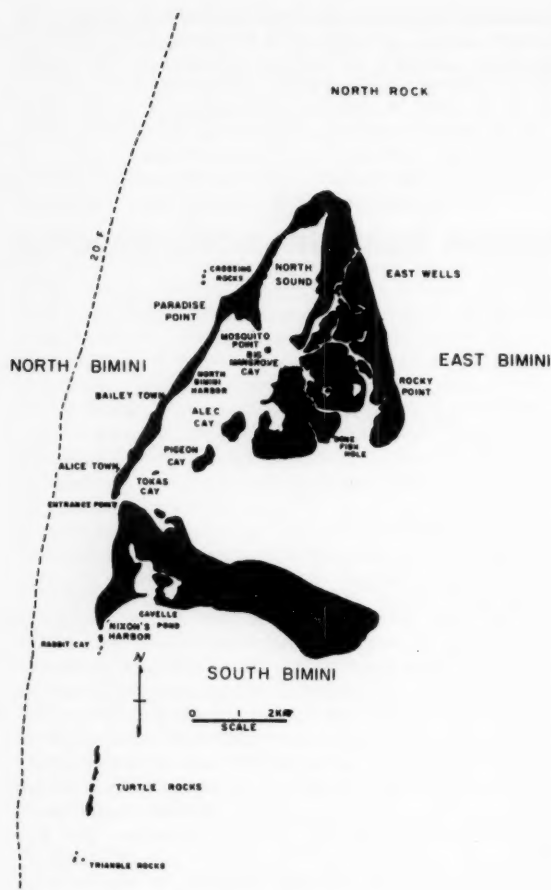
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Natural History. Summer collections were made by the writer while a member of a field group making a biogeographic survey of the northwestern part of the Great Bahama Bank under the direction of Professors N. D. Newell and John Imbrie and financed by grants from the Humble, Gulf, and Shell Oil companies. Winter collections were made while assisting Dr. Robert J. Menzies of the Lamont Geological Observatory, Columbia University, and were financed by that institution. The writer is indebted for field assistance to Mr. Edward Purdy, Mr. Robert Adlington, and Dr. Robert J. Menzies, and for laboratory assistance to Mr. Charles D. Wise. I wish to express my appreciation to Mr. I. G. Sohn and Dr. Stuart A. Levinson for helpful criticism of the manuscript.

CLASSIFICATION OF BAIRDIA

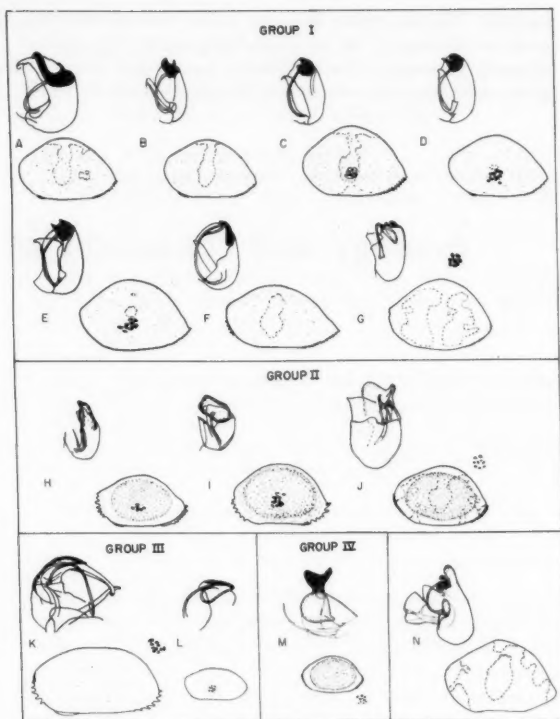
The genus *Bairdia* has been considered by many ostracode workers as having an extremely long time range; for example, Sylvester-Bradley (1950, p. 756), after studying the muscle scars of living and Paleozoic *Bairdia*, concluded: "... *Bairdia* is truly a long-ranging genus, extending certainly from Carboniferous to Recent times, and perhaps from the lower Paleozoic (more than one species having been recorded from the Ordovician)." On the other hand, Sohn (1958b, p. 1646) restricted the stratigraphic range of *Bairdia* to the Middle Devonian through Permian and stated: "Additional genera can and should be erected for post-Paleozoic species currently referred to *Bairdia*. Criteria for separating the groups are carapace shape, hingement, denticulate margins, presence of ventro-terminal loculae, such as illustrated for Cretaceous species by van Veen (1934, pls. 7-8) and the Paleozoic genus *Ceratobairdia* by Sohn (1954, pl. 2, fig. 19), combined with the soft anatomy of living species."



TEXT-FIGURE 1

LOCALITY MAP OF BIMINI ISLANDS, BAHAMAS

Opinions by ostracode specialists on the stratigraphic range of *Bairdia* have been based on comparisons of the carapace morphology of *Bairdia* of different ages. As the degree of morphological difference may indicate different categorical rank in different groups (Mayr, Linsley, and Usinger, 1953, p. 121), it is quite possible that the carapace morphology of *Bairdia* does not reflect taxonomic differences to the same degree as in other ostracode groups. With this as a hypothesis, the writer compared the appendages of different species assigned to *Bairdia* living in modern seas in order to see whether or not appendage morphology was as consistent throughout the genus as the carapace. Early in the study it was observed that considerable variation occurs in the morphology of the male copulatory organ among species of *Bairdia*, and attention was then concentrated on this organ. Undoubtedly, the work of Müller (1894) on the Gulf of Naples Ostracoda remains the most comprehensive and detailed study of the



TEXT-FIGURE 2

Carapaces, male copulatory organ, and muscle spots of ostracodes. Drawings are not to same scale.

A-G, group I: A, *Bairdia mediterranea* Müller; B, *Bairdia minor* Müller; C, *Bairdia frequens* Müller; D, *Bairdia obscura* Müller; E, *Bairdia decipiens* Müller; F, *Bairdia longevaginata* Müller; G, *Bairdia gigacantha* Kornicker, n. sp.

H-J, Group II: H, *Bairdia corpulenta* Müller; I, *Bairdia serrata* Müller; J, *Bairdia harpago* Kornicker, n. sp.

K-L, group III: K, *Bairdia reticulata* Müller; L, *Bairdia* sp. of de Vos.

M, group IV: *Bairdia arostrata* Kornicker, n. sp.

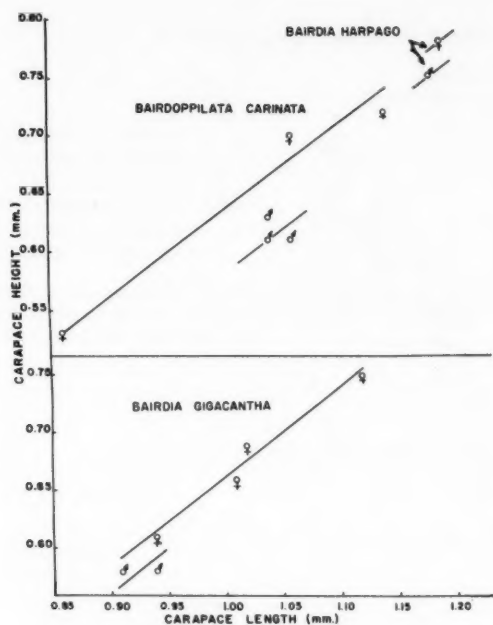
N, *Bairdoppilata carinata* Kornicker, n. sp.

The carapace and associated male copulatory organ and muscle spots may not be from the same individual. The carapaces shown are not all from males. Muscle scars when shown outside the carapace may not be oriented the same way as the carapace. Drawing of penis is oriented with head at top.

anatomy of *Bairdia*; it was a principal source of information relating to the morphology of the male organ of *Bairdia*.

"Differences in genitalia have been used in many groups in delimiting species because the differences indi-

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TEXT-FIGURE 3

Graph showing sexual dimorphism in carapaces of *Bairdia harpago* Kornicker, n. sp., *Bairdoppilata carinata* Kornicker, n. sp., and *Bairdia gigacantha* Kornicker, n. sp.

cate reproductive isolation" (Mayr, Linsley, and Usinger, 1953, p. 109). Groupings of species having similar male organs might constitute genera providing differences in the male organs from group to group are of sufficient magnitude. This satisfies the accepted definition of a genus as stated by Mayr, Linsley, and Usinger (1953, p. 48): "A genus is a systematic category including one species or a group of species of presumable common phylogenetic origin, which is separated from other similar units by a decided gap." The same authors (p. 48) suggest that the size of the gap be in inverse ratio to the size of the unit. Smaller gaps between genera derived from *Bairdia* might be justified because of the large number of species now assigned to *Bairdia*.

On the basis of similarities and differences in the morphology of the male copulatory organ, thirteen species of *Bairdia* were divided into four groups, each group having similar male organs which are considerable different from the male organs in the remaining groups (text-fig. 2). Although the groupings were based upon the male organ, a coincident result was the grouping of species having similar carapaces. Carapace differences between groups are, however, not as marked as differences in the anatomy of the male organ. This suggests that the carapace of *Bairdia* is quite conservative and

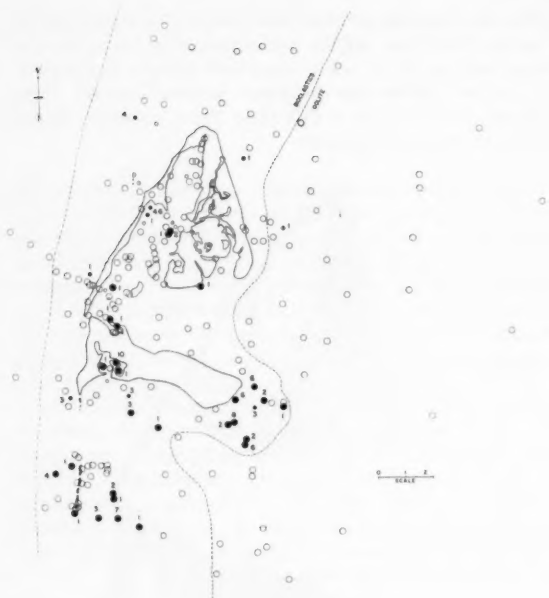
that the hypothesis that the carapace morphology of *Bairdia* does not reflect taxonomic differences to the same degree as in other ostracode groups is justified. Carapace differences between genera derived from *Bairdia* will be more subtle than those normally found between ostracode genera.

The differences in male organ structure between each of the four groups seems to be of the same degree as the difference in the male organ structure between *Bairdia* and the genus *Bairdoppilata*, which was separated from *Bairdia* on the basis of having hinge teeth not possessed by *Bairdia* (see text-fig. 2). This is considered to be a further indication that the gaps between the groups might be of generic importance. However, it is the writer's opinion that the taxonomy of the Ostracoda will be served best by basing new genera derived from *Bairdia* principally on recognizable gaps in carapace morphology, rather than on soft parts, which are absent in fossil forms. Until carapace morphology is better known, it seems best not to designate the groups established here on the basis of the male copulatory organ as being genera or subgenera, although they may actually deserve this designation.

Little attention has been given to patterns formed on the carapace of ostracodes by the distribution of opaque and translucent areas. Two species of *Bairdia* and one of *Bairdoppilata* collected in the Bahamas had patterns which were quite consistent for each species and were therefore useful in separating the species. A carapace was examined with a petrographic microscope by Robert L. Folk, who reported (1959, personal communication) that the opaque areas are formed by randomly oriented calcite grains, 1–2 μ in size, whereas the translucent areas have a prismatic calcite structure with fibers perpendicular to the surface.

SEXUAL DIMORPHISM

Variation in the length-height ratio appears to be characteristic of many species of *Bairdia*; for example, Kellett (1934, p. 123) states: "The variation within a species of the length-height ratio may be considerable, for example in a collection of *Bairdia beedei* from the same horizon and locality the length-height ratio varies from 1.76 to 1.65." In order to determine whether or not a part of this variation might be due to sexual dimorphism, length-height ratios were calculated on Bahamian specimens of Bairdiinae of which the sex had been determined by examination of the genitalia. The length-height ratios obtained for males were higher than those obtained for females of the same species (text-fig. 3). Sexual dimorphism was greatest in *Bairdoppilata carinata*, in which the length-height ratio was about 1.70 for males and about 1.55 for females. Measurements used in determining length-height ratios were made on the left valve, which overlaps and is usually larger than the right valve. In general, males did not attain the size of females.



TEXT-FIGURE 4

Distribution of living specimens of *Bairdia* and *Bairdoppilata* collected in the Bimini area. Large circles represent spot samples. Small circles represent trawl samples. Number represent number of specimens in a 10 cc. subsample removed from spot samples and the number of specimens collected in each trawl sample. Empty circles represent samples not containing living *Bairdia* or *Bairdoppilata*. The dashed line separates bioclastic sediments on the left side of the line from sediments containing about 90% oolite on the right side of the line.

OSTRACODE ECOLOGY

The literature on the ecology of post-Paleozoic ostracodes was summarized by Sohn (1957) in the "Treatise on Marine Ecology and Paleoecology." Sohn drew attention to the scarcity or lack of information concerning the ecology of living ostracodes in the following statement:

"The paleoecology of post-Paleozoic fossil ostracodes has been inferred from the known or assumed habits of living descendants of this group. The fact that most of the post-Paleozoic fossil ostracode genera contain species that are living at the present time gives credence to such inferences, but unfortunately data on the ecology of living ostracodes are relatively scarce."

The value of ostracodes as environmental indicators relative to other groups whose habits and habitat are better known has not been established with certainty. For example, Lozo (1943, p. 1069) stated: "Ostracodes, like ammonites, are apparently not as greatly affected by ecological conditions as foraminifera and are thus better qualified for time-stratigraphic determination."



TEXT-FIGURE 5

Distribution of empty carapaces of *Bairdia* and *Bairdoppilata* collected in the Bimini area. Carapaces were removed from 10 g. samples by alcohol flotation. Numbers represent total number of Podocopa per sample. Filling within circles indicates relative abundance of Bairdiinae: Completely filled circles - abundant; half-filled circles - common; quarter-filled circles - rare.

Benson (1959, p. 22), on the other hand, found that the ostracodes of the Todos Santos Bay region have about the same reaction to environmental change as the foraminifera.

In the present paper, the relationship of the genera *Bairdia* and *Bairdoppilata* to the water depth, temperature, substrate, and associated biota in diverse environments around Bimini is considered. Some of the literature containing information concerning the effect of these environmental factors on *Bairdia* has been summarized and in some instances reinterpreted.

DEPTH

Depth zonation of ostracodes has been observed by Remane (1933), Elofson (1941), and Benson (1959). The zonation probably results, not from changes in bathymetric pressure, but from changes in other environmental factors with depth, such as temperature, food availability, and bottom-current velocities.

The early explorations of the "Challenger" expeditions showed that the genus *Bairdia* is rare in the deep sea

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TABLE 1

DISTRIBUTION OF SPECIES OF *Bairdia* COLLECTED BY THE "CHALLENGER" EXPEDITION*

	Shelf 10-200 m.	Slope 200-2000 m.	2-3000 m., Abyssal	3000 m.
Number of species	15	8	5	3
Number of samples containing <i>Bairdia</i> (%)	68	71	45	14
Maximum number of <i>Bairdia</i> species per sample	4	3	1	2
Number of samples**	22	24	9	14

* Data derived from "Challenger" Report (Brady, 1880).

** Brady examined 150 samples but reported only those containing ostracodes. Sample localities of those not containing ostracodes were not given by Brady (1880).

TABLE 2

DEPTH DISTRIBUTION OF *Bairdia* AND *Bairdoppilata* IN THE BIMINI AREA

Depth (meters)	0-3		>3-6		>6-17		>17-21		>21-24	
	Number of individuals per sample									
Type sample	10 cc.	Trawl	10 cc.	Trawl	10 cc.	Trawl	10 cc.	Trawl	10 cc.	Trawl
Species										
<i>Bairdoppilata carinata</i>	11	22	6	7	0	0	0	0	0	0
<i>Bairdia gigacantha</i>	22	26	4	4	0	0	0	0	0	0
<i>Bairdia harpago</i>	13	3	3	0	0	0	3	0	0	0
<i>Bairdia arostrata</i>	3	1	2	0	0	0	1	0	1	0
<i>Bairdia dinochelata</i>	2	0	0	0	0	0	0	0	0	0
Total no. of samples	169	15	39	6	20	1	1	0	2	0
Total no. of samples with <i>Bairdia</i>	12	3	7	3	0	0	1	0	1	0
Total no. of samples with <i>Bairdoppilata</i>	7	3	3	4	0	0	0	0	0	0

and that the species diversity of *Bairdia* decreases with depth (Table 1). Several recent studies indicate that some species of *Bairdia* are restricted to certain depth zones. For example, Puri and Hulings (1957) listed *Bairdia* (one species) as common off Panama City, Florida, in the 20-21.7 meter depth zone, and possibly deeper; Curtis (MS.) found *Bairdia* (one species) restricted to the 15-25 meter depth zone in the Mississippi Delta area of the Gulf of Mexico; Hulings (1959) reported *Bairdia* as one of the genera characterizing the 200-3733 meter zone in the Gulf of Mexico and the 200-765 meter zone along the southern Atlantic Coast of the United States.

Collections from the Bimini area were from shallow water less than 24 meters deep. The number of samples collected in water deeper than 17 meters was insufficient to permit evaluation of the effect of the total depth-range sampled on species distribution. However, the depth distribution does indicate that the species under study are to be found in the largest numbers at depths shallower than 6 meters (Table 2). An exception to this pattern is *Bairdia arostrata*, which may become more abundant in deeper water. No specimens of *Bairdia* or

Bairdoppilata were found in intertidal waters, but samples containing large numbers of specimens were obtained in shallow subtidal water one meter deep.

TEMPERATURE

Tressler and Smith (1948, p. 48) considered temperature to be a major factor effecting the seasonal distribution of ostracodes in the Solomons Island, Maryland, region. The temperature of the water in the Bimini area from which collections were made varied between 24° and 31° C. The temperature of the water in North Bimini Harbor was recorded as low as 14° C. on Jan. 12, 1956 (Krumholtz, personal communication), but no collections were made at that temperature. The genus *Bairdia* apparently is not limited to a narrow temperature range, because specimens of *Bairdia* were collected during the "Challenger" expedition from water at temperatures as low as 1.2° C. (Brady, 1880), which is in considerable contrast to the high water-temperatures in the Bimini area. Large numbers of *Bairdia*, however, may reflect warm seas. Brady (1880, p. 48) made the following statement concerning the genus *Bairdia*: "This is a widely dispersed genus, attaining, apparently, its

greatest development in the tropical and southern seas, in dredgings from which regions the number of specimens of *Bairdia* not infrequently exceeds that of all the other Ostracoda together; the individuals, however, though numerous, are usually found to belong in each gathering to one, or at most two, predominant species."

Temperature also seems to exert major control over the number of species of *Bairdia* inhabiting a region, only a few species living in areas where the water is below 10° C. For example, Sars (1923) reported only one species of *Bairdia* living in the cold waters around Norway, whereas, Müller (1894) reported eleven species of *Bairdia* from the Gulf of Naples, where the water temperature is about 14° C. Furthermore, in the collections of the "Challenger" from the Australasian area, which includes the coasts of Australia, New Zealand, and the Eastern Archipelago south of the Equator, fourteen species of *Bairdia* were collected from water having a temperature above 10° C., whereas only four species were collected in colder, deeper water (Brady, 1880). The large number of species of *Bairdia* (ten species are not uncommon in a formation) found in Permian and Pennsylvanian shales and limestones (Bassler and Kellett, 1934) may reflect the warm seas in which they were deposited.

SUBSTRATE

Bairdia were collected by the "Challenger" expedition on many different substrates, including mud, sand, gray ooze, sandy mud and shells, *Globigerina* ooze, rock, and coral (Brady, 1880). Brady (1880, p. 26) reported *Bairdia hirsuta* Brady from red clay at station 296; however, that station is recorded by Thomson (1880, p. 58) as having *Globigerina* ooze. Only one species of *Bairdia* was taken alive during the "Challenger" expedition, so that the possibility exists that empty carapaces might have been transported from the habitat in which the animals lived.

In the Gulf of Naples, live *Bairdia* were collected from among calcareous algae and in shell detritus (Müller, 1894). Benson (1959, p. 42) reported a species of *Bairdia* limited to fine to very fine sand in the Bahía de Todos Santos, Baja California, and in coarser sand of fringing tide pools. Puri and Hulings (1957) reported a species of *Bairdia* inhabiting medium- to fine-grained, well sorted noncarbonate sands in the Panama City area of the Gulf of Mexico and in carbonate sands in Florida Bay. In the Paleozoic, according to the faunal lists of Bassler and Kellett (1934), the genus *Bairdia* seems to be about equally abundant in shale and limestone. Geis (1932, p. 176) reported *Bairdia* from the Mississippian Spargen limestone, which is oolitic.

The two major subdivisions of sediment in the Bimini area are bioclastics and oolite (see Kornicker, 1958, for further discussion of Bimini sediments). Specimens of *Bairdia* and *Bairdoppilata* were collected in most of the environments underlain by bioclastics but were rare or absent in oolite areas (text-fig. 4). In general, all genera

of ostracodes were rare or absent in areas of oolite (text-fig. 5). Kornicker (1958, p. 213) believed that ostracodes that normally burrow into sediment are deterred from occupying oolite areas because of the difficulty of burrowing into oolite, which has a very high bulk density. A different explanation is required for the absence of *Bairdoppilata carinata* and the species of *Bairdia* from the oolite area because observations of these species in laboratory aquaria indicate that they are bottom surface crawlers and do not burrow. It is possible that these species do not inhabit the oolite sediments because they find crawling difficult on oolite owing to its good sorting and the shape and size of the individual ooids. A similar difficulty might be experienced by a dog walking on cannon balls or a mouse on marbles. This hypothesis is supported by laboratory observations, which showed that specimens of *Bairdoppilata leneri* often fall on their sides when walking on oolite.

Six individuals of *Bairdoppilata carinata* (all mature specimens) were placed in a small vial containing oolite and were periodically observed. No food was added to the vial during the observation period. Under these conditions, the average life span of the six individuals was 29 days; one specimen lived 47 days. Although the data are too few to be conclusive, it does suggest that oolite is not inhibiting. None of the specimens burrowed into the oolite during the period of observation.

A considerable part of the bottom in the Bimini area is rock. Both rock and sand bottoms support varying amounts of plants and animals. The rock bottom is usually covered by at least a sprinkling of sand a millimeter or so in thickness. Depressions in the rock are usually sand-filled. Species of *Bairdia* and *Bairdoppilata carinata* lived on both rock and sand substrate in about the same numbers (Table 3).

ASSOCIATED BIOTA

The biota in the Bimini area with which *Bairdoppilata carinata* and the species of *Bairdia* were associated did not have a consistent or typical composition, but was quite variable. The largest single collection of Bairdiinae was obtained in North Bimini Harbor, near Mosquito Point, from a shallow channel one meter deep, which contained an accumulation of mangrove debris barely covering the bottom. The algae *Penicillus* and the jellyfish *Cassiopeia* were abundant. A sample obtained by dragging a net along the bottom produced 23 specimens of *Bairdoppilata leneri*, 20 specimens of *Bairdia gigacantha*, and 3 specimens of *Bairdia harpago*. A slow current passed over the bottom, and the area seemed well oxygenated. Living *Bairdia* were not obtained from heavy accumulations of mangrove debris that gave off hydrogen sulfide gas. An empty carapace of a *Bairdia* collected from this environment was decalcified. This supports a hypothesis of Sohn (1958a, p. 735) that wrinkled films of ostracode carapaces found in sedimentary rocks represent penecontemporaneous decalcification.

RECENT BAIRDIINAE

TABLE 3

NUMBERS OF LIVE *Bairdia* INDIVIDUALS COLLECTED FROM
ROCK AND SAND BOTTOM IN THE BIMINI AREA

Species	Number of individuals*	
	Rock bottom	Sand bottom
<i>Bairdia gigacantha</i>	13	13
<i>Bairdoppilata carinata</i>	10	7
<i>Bairdia harpago</i>	13	5
<i>Bairdia arostrata</i>	7	4
<i>Bairdia dinochelata</i>	1	3
	44	32

* The number of individuals refers to the number of living specimens in a 10 cc. subsample removed from bottom sediment obtained with an Emory grab sampler.

The species *Bairdia harpago* seemed especially abundant in a passage connecting the east and west parts of Cavelle Pond in 0.6 meter of water. The rock bottom there was covered by a thin veneer of sand. The dominant plant was the alga *Laurencia*. Other algae present were *Halimeda* and *Penicillus*; *Thalassia* was sparse. Sponges were common. The only coral living there was *Siderastrea radians*. *Bairdia harpago* was also collected in sand areas having thick growths of *Thalassia* and *Laurencia*, as well as from rock areas with a thin veneer of sand which supported sea whips, sea fans, stony corals, and the algae *Caulerpa*, *Laurencia*, and *Rhipocephalus*.

Bairdia gigacantha was very abundant in water 2 meters deep off the east shore of South Bimini. Collections from that area produced about equal numbers from rock bottoms supporting sea whips, sponges, the coral *Porites asteroides*, and the algae *Laurencia*, *Penicillus*, and *Halimeda*, and from calcareous sand bottoms supporting dense growths of *Thalassia* and *Laurencia*. Live ostracodes were more abundant along the east shore of South Bimini than in any other area sampled (Kornicker, 1958). Other small crustaceans, such as amphipods and copepods, were also very abundant in this area. The reason for the abundance of bottom life here is not known, but it does not appear to be the result of associated biota.

SALINITY

The genus *Bairdia* in today's seas is generally restricted to water having normal salinity of 30 to 40 parts per thousand. An abundance of *Bairdia* specimens in ancient sediments may indicate that deposition took place in marine water of normal salinity.

Müller (1894) collected many species of *Bairdia* in the Gulf of Naples, where the salinity is about 38.6 parts per thousand. *Bairdia* specimens were found to be particularly abundant in the Australasian region, where the salinity is about 35.0 parts per thousand (Brady, 1880). *Bairdia* has been reported (only one or two species) from offshore areas in the Gulf of Mexico where

normal marine salinity of about 35.0 parts per thousand is encountered (Curtis, MS.; Hulings, 1959). A species of *Bairdia* was collected from the Gulf of Mexico off Panama City, Florida, in water having a salinity of 35.6 to 36.8 parts per thousand and from Florida Bay, where salinities are about 37 parts per thousand (Puri and Hulings, 1957). On the other hands, *Bairdia* specimens were conspicuously absent from San Antonio Bay (Swain, 1955) and from Mesquite and Aransas Bays (Engel, MS.), Texas, where salinities are usually below 20 parts per thousand.

Bairdia specimens were not found in the Chesapeake Bay region near the mouth of the Patuxent River, where salinities of 10.0 to 19.4 parts per thousand were recorded (Tressler and Smith, 1948). *Bairdia* was absent from Alligator Harbor, an estuary in Franklin County, Florida, where the salinity range is approximately 28 to 34 parts per thousand, with greater fluctuations not uncommon (Puri and Hulings, 1957). *Bairdia* is absent from the Laguna Madre of Texas, where salinities above 45 parts per thousand are often encountered (investigation now under way by Kornicker and Wise).

During the time when the collections were made in the Bimini area, the salinity remained within the 30-40 parts per thousand range considered by Hedgpeth (1951) to represent normal marine water, except in the upper part of North Sound, where salinities of 46.5 parts per thousand were recorded (Turekian, 1957). Live individuals of *Bairdoppilata carinata* and species of *Bairdia* were not collected in North Sound; however, empty carapaces were found in the sediment in the lower part of the sound but were absent in the upper part, where salinities of 42 parts per thousand or higher had been recorded.

CONCLUSIONS

Consideration of similarities and differences in the structure of the male copulatory organ of Recent *Bairdia* indicates that the carapace of the genus *Bairdia* is resistant to change and does not reflect, to the same degree as the male copulatory organ, major morphological differences which might normally result in the definition of new genera.

Males of *Bairdia*, and especially of *Bairdoppilata*, of the species studied have higher length-height ratios than females and are smaller.

Bairdia is abundant in subtidal and shelf sediments, common in slope sediments (200-2000 meters), but rare in abyssal sediments (deeper than 2000 meters), and is usually absent from intertidal sediments. It is apparently restricted to waters of normal salinity. An abundance of individuals and a high diversity of species may reflect shallow, warm water, above 10° C. *Bairdia* has been collected from many different kinds of sediment but has not been reported from abyssal red clays and is scarce in Recent shallow-water oolite. It may be scarce in oolite because of the physical difficulty of crawling over the surface of oolite sediment.

SYSTEMATIC DESCRIPTIONS

Subclass OSTRACODA Latreille

Order PODOCOPA G. O. Sars

Family BAIRDIIDAE G. O. Sars, 1887

Subfamily BAIRDIINAE Sars, 1923

Genus *Bairdia* M'Coy, 1844

Type species: Bairdia curta M'Coy, 1844, *Synopsis Carboniferous limestone fossils of Ireland*, p. 164, pl. 23, fig. 6.

Generic characteristics: Shell more or less rhomboid in outline, with the anterior end rounded ventrally and the posterior end angular and produced. The midportion, especially in the right valve, tends to be straight. Left valve larger than the right and usually overlapping it, except in the anterior and posteroventral parts of the shell. Hinge adont. Surface smooth or punctate; living specimens often covered with hair.

Both pairs of antennae very slender, the anterior antennae (antennules) having long thin setae on the ends. The penultimate joint of the second antennae is unusually long and slender. Three pairs of thoracic legs are long and narrow. The furca bears 6-8 long slender setae; two or three of these may be considered terminal; four or five are situated along the ventral margin. Additional short setae may be present along the posterior margin of the furca near the distal end.

***Bairdia gigacantha* Kornicker, new species**

Plate 1, figure 2a-c; text-figures 6A-J, 10A, D

Diagnosis: Carapace in lateral view more or less oval in outline; greatest height about in the middle; dorsal margin broadly arched. Carapace of male not as high as female; length-height ratio of females about 1.53, of males about 1.58. Anterior margin broadly rounded, with anterodorsal angle above midheight of valve; posterior beak bluntly acuminate, slightly below midheight. In dorsal view broadly ovate; greatest width about in the middle; both ends pointed. Left valve with a series of anterior and posterior spines; right valve with an anterior and posterior frill. Valves unequal, the left overlapping the right. Surface apparently smooth but with small pits visible under high magnification. Muscle scars consisting of a cluster of about nine ovoid bosses near center of valve. Long black hairs project from carapace surface. Both valves with opaque and translucent areas forming a more or less consistent pattern for the species. Opaque area at center of valve mushroom-shaped, with one or more small transparent areas in upper posterior part. Lobate opaque areas along anterior, posterior, and dorsal margins of carapace.

The hinge of the left valve consists of a narrow shallow groove above a thin straight bar at the straight dorsal contact. The area between the narrow groove and the

dorsal edge of the valve is extremely broad. Beneath the bar is a recessed area which broadens at each end. The hinge of the right valve consists of a bar with a narrow groove along its dorsal side, which engages with the groove and bar of the left valve. The shelf forming the lower margin of the groove projects outward farther than the bar above the groove and fits into a recessed area below the bar of the left valve. The shelf projects very slightly at the ends of the straight portion of the hinge. The projection is more noticeable at the anterior than at the posterior end. Ventrally, a marginal ledge is found on the left valve on either side of the ventral overlap area. This ledge, upon which the edge of the right valve rests when the valves are closed, fades out above the ventral overlap area. The ventral overlap area of the left valve is well developed.

Body of living animal brown, with appendages bearing black setae. Brown color of body visible from outside through translucent areas of carapace. Furca bearing six setae; two proximal setae of about the same length and smaller than the other setae; third and fourth setae from proximal end of about the same size as the sixth clawlike seta; fifth seta clawlike, with secondary setae at distal end. One specimen had two small "points" on the posterior edge of the furca near the distal end. Male copulatory organ ovoid, with head consisting of two parts, the larger being hook-shaped (text-fig. 6G).

Comparisons: *Bairdia gigacantha* does not have the prominent pits of the holotype of *Bairdia bradyi* van den Bold (1957, p. 236), nor is the posterior end as acute.

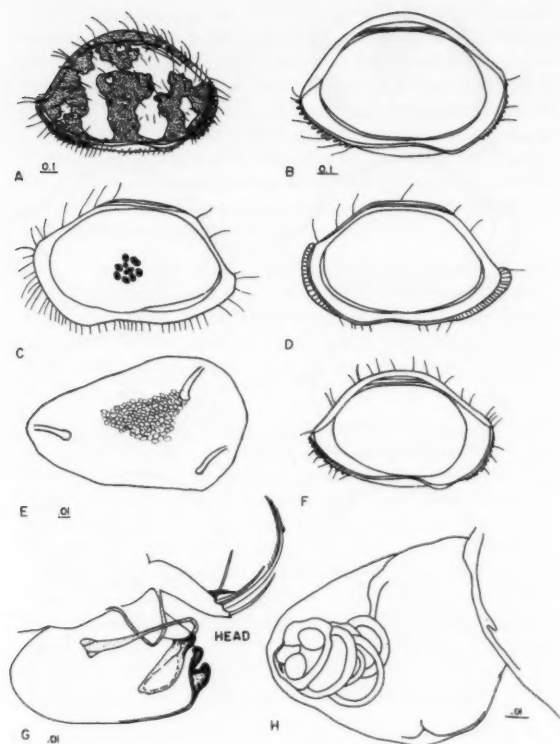
Shell measurements (in mm.):

Specimen number	Length	Height	Length-height ratio	Sex	Valve
247-9-3 (holotype)	1.02	0.69	1.48	female	left
122B-1	0.94	0.61	1.54	female	left
122B-16	1.01	0.66	1.55	female	left
122B-4	0.91	0.58	1.57	male	left
122B-7	0.94	0.58	1.62	male	left
247-9-2	1.12	0.75	1.49	female	left

Material: Fifty-five specimens were collected in the Bimini area. Sex was determined in six individuals, four females and two males. The holotype, specimen no. 247-9-3, is illustrated in text-figure 6B, D-E, H, and in plate 1, figure 2b-c.

Occurrence: Specimens were collected in about the same numbers on rock and bioclastic sand substrates. No individuals were collected from oolitic sand, from areas exposed at low tide, or in the entrance to the main channel of North Bimini Harbor, where high current velocities are encountered. Rock bottom areas from which collections were made support sponges, corals, algae, *Thalassia*, echinoderms, crabs, crayfish, and worms. Sand bottom areas usually support *Thalassia*,

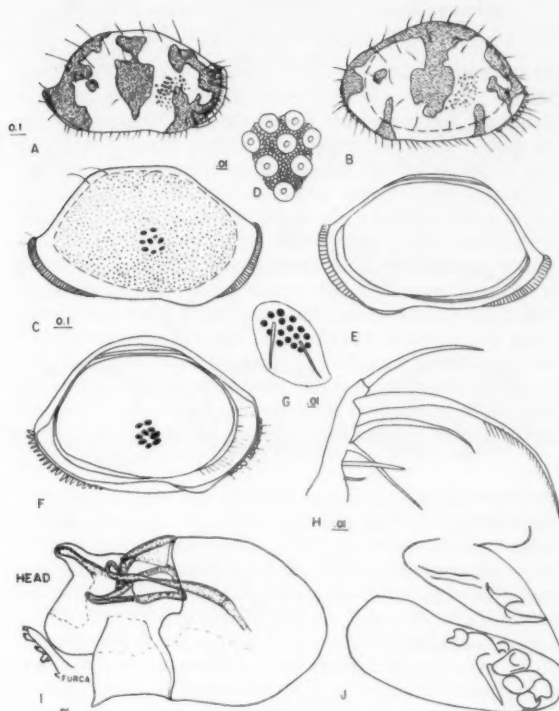
RECENT BAIRDIINAE



TEXT-FIGURE 6

Bairdia gigacantha Kornicker, n. sp. A, view of carapace of specimen number 247-9-2, a female, from the right side (part of right valve covered with pattern is more opaque than remainder of valve); B, view of left valve of specimen number 247-9-3, a female (holotype), from outside; C, view of inside of right valve of specimen number 247-9-1, a female, showing muscle scars; D, view of right valve of specimen number 247-9-3 from inside; E, detail of carapace wall of specimen number 247-9-3 from outside; F, view of left valve of specimen number 122B-7, a male, from inside; G, penis and furca of specimen number 122B-7; H, female genital organ of specimen number 247-9-3. Figures with similar magnification: A; B-D, F; E; G; H.

the alga *Laurencia* as well as smaller numbers of other species of algae, corals, sponges, and echinoderms. *Bairdia gigacantha* was collected in water ranging in depth from 0.6 to 5 meters. This species was not collected in the few samples obtained from greater depths. Collections were made in May, June, and December, 1956. The temperature of the water during the time of collection in December was about 24° C. In May and June, the water temperatures at the collection sites ranged from 26.5° to 29.5° C. The salinity of the water was about 37.5 parts per thousand.



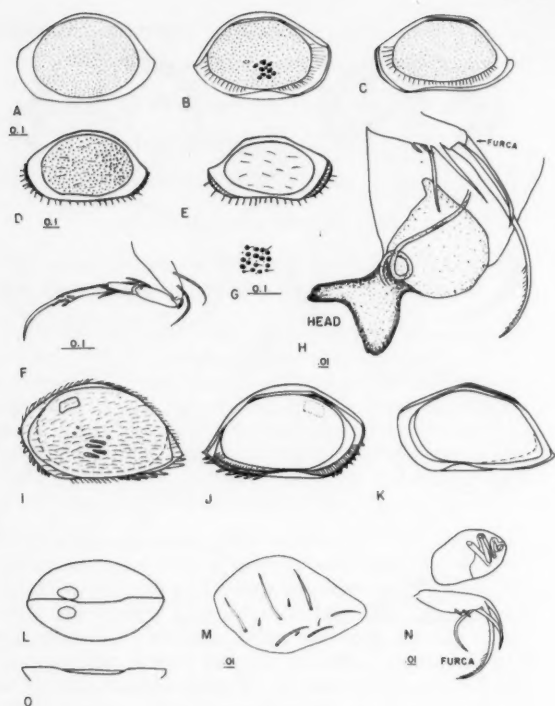
TEXT-FIGURE 7

Bairdia harpago Kornicker, n. sp. A, view of right valve of specimen number 122B-10, a male, from outside (patterned area is more opaque than remainder of valve); B, view of left valve of specimen number 122B-10 from outside; C, view of right valve of specimen number 122B-12, a female (holotype), from outside; D, detail of carapace wall of specimen number 122B-12 from outside; E, view of right valve of specimen number 122B-12 from inside; F, view of left valve of specimen number 122B-12 from inside; G, detail of carapace wall of specimen number 122B-12 showing distribution of surface hairs; H, furca of specimen number 122B-10; I, penis of specimen number 122B-10; J, female genital organ of specimen number 122B-12. Figures with similar magnification: A-B; C, E-F; D; G; H; I; J.

Bairdia harpago Kornicker, new species

Plate 1, figure 1a-b; text-figure 7A-J

Diagnosis: Shell in lateral view rhomboid oval in outline; greatest height about in the middle; dorsal margin broadly arched. Carapace of male not as high as that of female; length-height ratio of male (one specimen) 1.58, of female (one specimen) 1.52. Anterior margin broadly rounded, with anterodorsal angle above mid-height of valve; posterior beak bluntly acuminate, slightly below midheight. In dorsal view broadly ovate;



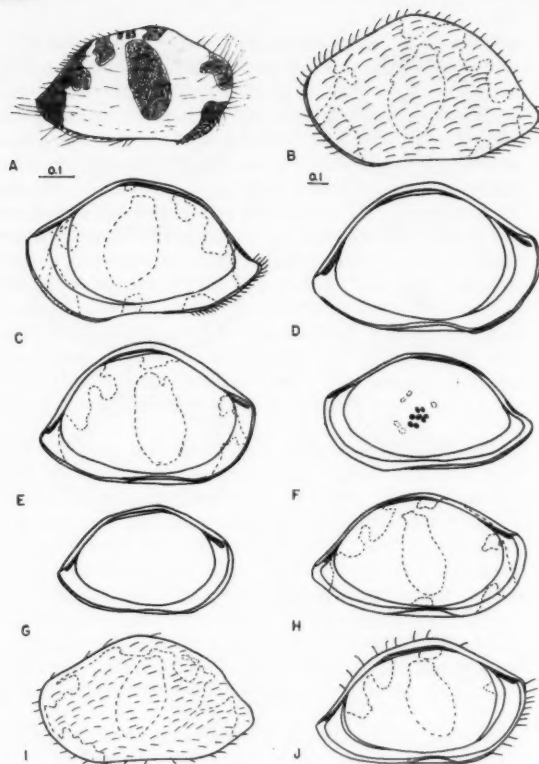
TEXT-FIGURE 8

A-H, *Bairdia arostrata* Kornicker, n. sp.: A, view of left valve of specimen number 92 (holotype) from outside; B, view of left valve of specimen number 92 from inside; C, view of right valve of specimen number 92 from inside; D, view of left valve of specimen number 122C-1, a male, from outside; E, view of right valve of specimen number 122C-1 from outside; F, leg of specimen number 122C-1; G, Detail of carapace surface of specimen number 122C-1; H, furca and penis of specimen number 122C-1.

I-O, *Bairdia dinochelata* Kornicker, n. sp.: I, view of left valve of specimen number 500-1, a female (holotype), from outside; J, view of left valve of specimen number 500-1 from inside; K, view of right valve of specimen number 500-1 from inside; L, sketch of dorsal view of specimen number 500-1; M, Detail of surface of specimen number 500-1; N, furca and female genital organ of specimen number 500-1; O, dorsal view of dorsal edge of left valve.

Figures with similar magnification: A-C, I-K; D-E; F; G; H; L; M; N; O.

greatest width about in the middle; both ends pointed. Left valve with a series of anterior and posterior spines; right valve with an anterior and posterior frill. Valves unequal, the left overlapping the right. Surface with large pits. Muscle scars consisting of a cluster of about nine ovoid bosses near center of valve. Long black hairs project from carapace surface. Both valves of carapace



TEXT-FIGURE 9

Bairdoppilata carinata Kornicker, n. sp. A, view of right side of carapace of specimen number 122B-6, an immature female, from outside (patterned area is more opaque than remainder of valve); B, view of left valve of specimen number 122B-2, a female (holotype), from outside; C, view of right valve of specimen number 122B-2 from inside; D, view of left valve of specimen number 122B-2 from inside; E, view of left valve of specimen number 122B-5, a female, from inside; F, view of right valve of specimen number 122B-11, a male, from inside; G, view of left valve of specimen number 122B-6, an immature female, from inside; H, view of left valve of specimen number 122B-11 from inside; I, view of left valve of specimen number 122B-3, a male, from outside; J, view of left valve of specimen number 122B-3 from inside. Figures with similar magnifications: A, B-J.

with opaque and translucent areas forming a more or less consistent pattern for the species; centrally located opaque area spade-shaped; anterior and posterior opaque areas lobate.

The hinge of the left valve consists of a shallow groove above a very narrow straight bar at the straight dorsal contact; there is a broad area between the groove and the dorsal edge of the valve; the recessed area beneath the bar broadens at each end. The hinge of the right

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valve consists of a bar with a narrow groove along its dorsal side, which engages with the groove and bar of the left valve. The shelf forming the lower margin of the groove fits into the recessed area below the bar of the left valve. Ventrally, a marginal ledge is found on the left valve on either side of the ventral overlap area. This ledge, upon which the edge of the valve rests when the valves are closed, fades out above the ventral overlap area. The ventral overlap area and ventral lip of the left valve are well developed.

Furca with six setae; first seta from proximal end shortest; second seta about twice the length of the first; third seta about three times the length of the first; fourth and sixth setae slightly more than half the length of the fifth seta. The male copulatory organ is complex (text-fig. 7I).

Comparisons: The carapace of *Bairdia harpago* is similar in shape to that of *Bairdia gigacantha*. It differs from *Bairdia gigacantha* in being coarsely pitted and in having a different pattern of opaque and translucent areas on the carapace. For example, the spade-shaped, centrally located opaque area in *Bairdia harpago* does not come in contact with the ventral margin, whereas the opaque area in *Bairdia gigacantha* does. The carapace of *Bairdia harpago* resembles the carapace of *Bairdia bradyi* van den Bold, which was collected in the Bahamas by Brady (1868, p. 56, text-figs. 4-6, pl. 7). Brady's description is inadequate for comparison, and the holotype is not available.

Shell measurements (in mm.):

Specimen number	Length	Height	Length-height ratio	Sex	Valve
122B-10	1.18	0.75	1.58	male	left
122B-12 (holotype)	1.19	0.78	1.52	female	left
	1.19	0.68	—	female	right

Material: Twenty-one specimens were collected in the Bimini area. Appendages of three specimens were examined, one male and two females. The holotype, specimen no. 122B-12, is illustrated in text-figure 7C-G, J, and in plate 1, figure 1a-b.

Occurrence: Specimens were collected on both sand and rock bottom areas. This species is the only *Bairdia* collected in Cavalle Pond, a shallow pond on South Bimini which has restricted circulation with Bank water. It may be particularly abundant in the passage connecting the east and west segments of this pond. *Bairdia harpago* was collected in water ranging in depth from 1 to 28 meters. As very few samples were obtained at depths of 18 meters or greater, it is possible that this species is more abundant in deeper waters. Individuals were collected in June and December of 1956. The water temperature in December at the time of collection was approximately 24° C. In May, the water temperature at the collecting sites ranged from 27° to 31° C. Water salinities were about 37.5 parts per thousand.

Bairdia arostrata Kornicker, new species

Plate 1, figure 3a-b; text-figure 8A-H

Diagnosis: Carapace in lateral view rhomboid oval in outline; greatest height about in the middle; dorsal margin broadly arched; ventral margin nearly straight; posterior margin pointed; anterior margin rounded. In dorsal view broadly ovate; greatest width about in the middle; both ends acute. Valves unequal, the left overlapping the right; hinge adont. Left valve with a series of anterior and posterior short spines. Right valve with anterior and posterior frill. Surface pitted and hairy, with marginal radial pores. Muscle scars consist of about ten oval bosses located below center of valve. Carapace brown, with central area darker than periphery. Furca with six setae; two small proximal setae of about the same length; third and fourth setae of about the same size, shorter than the shorter of the two terminal clawlike setae. Male copulatory organ large and bifurcate (text-fig. 8H).

Comparisons: *Bairdia arostrata* resembles *Bairdia corpulenta* Müller in shape. It differs from that form in the bifurcate nature of the male organ and in having only four setae on the ventral margin of the furca following the two terminal setae. *Bairdia arostrata* differs from *Bairdia harpago* in that the peniproximal seta on the ventral margin of the furca is equal in length to the proximal seta. *Bairdia arostrata* is also smaller than *Bairdia harpago*; the male has a bifurcate copulatory organ; and the carapace is not differentiated into opaque and translucent areas.

Shell measurements (in mm.):

Specimen number	Length	Height	Length-height ratio	Sex	Valve
92 (holotype)	0.71	0.48	1.48	—	complete
122C-1	0.86	0.50	1.72	male	complete

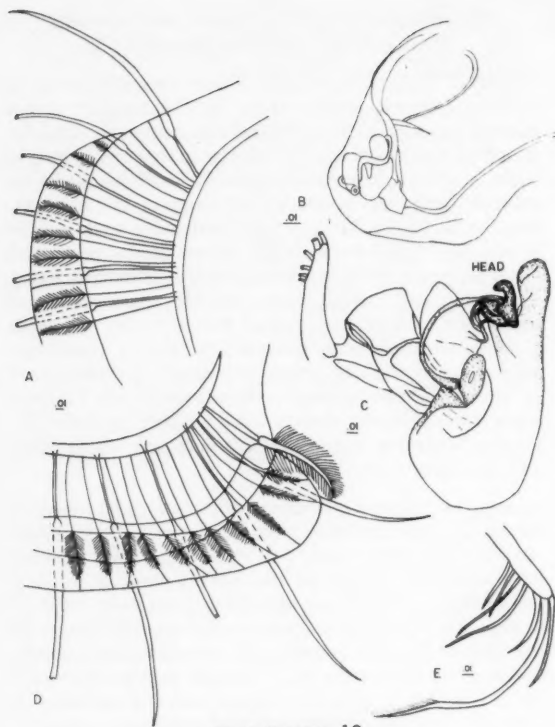
Material: Twelve specimens were collected in the Bimini area. One individual, a male, was dissected. The holotype, specimen no. 92, is illustrated in text-figure 8A-C and in plate 1, figure 3a-b.

Occurrence: Specimens were collected on both rock and sand bottoms. This species was collected at water depths ranging from 1 to 22 meters. This species may be more abundant in deep water. Specimens were collected in May, June, and December, 1956. Water temperature in December at the time of collection was approximately 24° C. Water temperature in May and June at collecting sites ranged from 27.0° to 29.0° C. Water salinity was about 37.5 parts per thousand.

Bairdia dinochelata Kornicker, new species

Plate 1, figure 4a-d; text-figure 8I-O

Diagnosis: Carapace in lateral view rhomboid oval in outline; greatest height slightly anterior to the middle; dorsal margin broadly arched; ventral margin nearly straight; ventral side flattened. Anterior margin broadly rounded, with anterodorsal angle above midheight.



TEXT-FIGURE 10

A, D, *Bairdia gigacantha* Kornicker, n. sp.: A, antero-dorsal corner, at high magnification; D, posteroventral corner, at high magnification; both A and D are from specimen number 247-9-1, which was decalcified with dilute hydrochloric acid before being drawn.

B-C, E, *Bairdoppilata carinata* Kornicker, n. sp.: B, female genital organ of specimen number 122B-5; C, penis of specimen number 122B-3; E, furca of specimen number 122B-5. Figures with similar magnification: A, D; B; C; E.

Posterior beak acuminate, ending in a short spine and located well below midheight. In dorsal view broadly ovate; greatest width about in the middle; pointed at both ends. Valves unequal, the left overlapping the right. Considerable overlap along anterior and postero-dorsal margins, so that hinge line appears sinuous in dorsal view; hinge adont. Left valve with anterior and posterior marginal spines. Carapace finely punctate, with many short hairs and marginal radial pores. Four elongate muscle scars below center of valve; each scar appears to consist of linearly arranged, closely spaced bosses. Three faint ovoid scars are scattered above elongate scars. Carapace dark brown except over two irregular areas in the anterodorsal part of the valve. Ventrally, a marginal ledge is present on either side of ventral overlap area. This ledge, upon which the ventral edge of the right valve rests when the valves are closed, fades out above the ventral overlap area.

Furca with six setae; two proximal setae of about the same length, shorter than other setae; third, fourth, and sixth setae of about the same length, slightly longer than half the length of the fifth seta. Male unknown.

Comparisons: *Bairdia dinochelata* differs from the other ostracodes described in this paper in having four large horizontal muscle scars.

Shell measurements (in mm.):

Specimen number	Length	Width	Height	Length-height ratio	Sex	Valve
500-1 (holotype)	0.84	—	0.51	1.65	female	left
87-G	0.78	0.46	0.48	1.62	—	complete

Material: Four specimens were collected in the Bimini area. One specimen was dissected, a female. The holotype, specimen no. 500-1, is illustrated in text-figure 8I-N and in plate 1, figure 4a-b.

Occurrence: Specimens were collected on both sand and rock bottoms. Individuals were collected in water ranging in depth from 1.5 to 3.5 meters. Specimens were collected in May and June of 1956; none were found in collections made in December of 1956. Water temperatures taken during the time of collection ranged from 27.0° to 28.5° C. The salinity of the water was approximately 37.5 parts per thousand.

Genus *Bairdoppilata* Coryell, Sample, and Jennings, 1935

Type species: *Bairdoppilata martyni* Coryell, Sample, and Jennings, 1935, Amer. Mus. Nat. Hist., Novitates, no. 777, p. 3, text-figs. 1-2.

Generic characteristics: Carapace bairdioid in lateral view. Left valve larger than the right and overlapping it on all margins, most strongly at dorsal and midventral contacts. A short series of crenulations supported on a small platform are present beneath the overlap margin at anterior and posterior angulations of left valve. Right valve with a series of crenulations on edge of valve which engage with crenulations on left valve.

Bairdoppilata carinata Kornicker, new species

Plate 1, figure 5a-e; text-figures 9A-J, 10B-C, E

Diagnosis: Shell in lateral view rhomboid oval in outline; greatest height slightly posterior to the middle. Difference in height of carapace of females and males considerable, females having a length-height ratio of about 1.55 and males 1.70. Anterior margin broadly rounded; anterodorsal angle above midheight of valve; posterior beak bluntly acuminate and slightly below midheight. In dorsal view broadly ovate; greatest width about in the middle; both ends pointed. Valves unequal, the left overlapping the right. Surface smooth; small pits visible under high magnification. Profuse long black

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hairs project from carapace. Muscle scars of male consisting of about nine oval bosses clustered around center of valve, with about five less distinct scars around periphery of cluster. Muscle scars of female centrally located, but individual scars extremely difficult to distinguish. Both valves with opaque and translucent areas forming a more or less consistent pattern; centrally located opaque area ovoid and inclined posteriorly; lobe-shaped opaque areas follow the anterior and posterodorsal margins.

The hinge in the left valve consists of a narrow groove above a thin straight bar at the straight dorsal contact; below the bar at each end is a short recessed area. Just below the anterior and posterior dorsal angles are short, low crenulated ridges. The hinge in the right valve consists of a bar with a groove along its dorsal side, which engage with the groove and bar in the left valve. Below the groove is a shelf, which does not project as far out as the bar above the groove except at each end, where this portion of the shelf engages the recessed areas below the bar of the left valve. The edge of the valve above the anterior and posterior dorsal angles is dentate, engaging the crenulations below the anterior and posterior dorsal angles of the left valve. A continuous ledge, against which the edge of the right valve rests when the carapace is closed, runs from the anterior ventral angle along the inside of the ventral margin, where it is best developed, to the posterior dorsal angle. The ledge is very faint at the anterior and posterior ends. Ventral overlap of the left valve is poorly developed.

Body of animal brown, with appendages bearing black setae. Furca with seven setae; two proximal setae are of about the same length and smaller than remaining setae; third seta somewhat longer than fifth seta; fourth seta about three-fourths as long as the sixth seta; fifth seta of approximately the same length as seventh seta. In one specimen, the third seta was of the same length as the fourth seta. Triangular and rectangular flaps lie between the head of the male copulatory organ and the furca. (see text-fig. 10C). Male copulatory organ has a lobe extending over the hooklike head of the organ.

Shell measurements (in mm.):

Specimen number	Length	Height	Length-height ratio	Sex	Valve
122B-2 (holotype)	1.14	0.73	1.56	female	left
122B-36	1.06	0.61	1.74	male	left
122B-9	1.04	0.63	1.68	male	left
122B-13	1.04	0.63	1.68	male	left
122B-11	1.04	0.61	1.72	male	left
122B-5	1.06	0.70	1.52	female	left
122B-6	0.86	0.53	1.62	female	left
				(immature)	

Material: Forty-five specimens were collected in the Bimini area. Sex was determined in seven individuals,

four males and three females. The holotype, specimen no. 122B-2, is illustrated in text-figure 9B-D and in plate 1, figure 5b-c.

Occurrence: Specimens were collected in about the same numbers on bioclastic sand and on rock surfaces with little sand cover. No individuals were collected from oolitic sand, areas exposed at low tide, or in the entrance to the main channel at North Bimini, where high water-velocities are encountered. Rock bottom areas from which collections were made support sponges, corals, algae, and *Thalassia*. Sand bottom areas support *Thalassia*, *Laurencia*, and other marine algae, worms, echinoderms, sponges, and corals. Sea whips and sea fans were present on rock bottom in the channel of North Bimini Harbor and on the Bank west and south of the Biminis. *Bairdoppilata carinata* was collected in water ranging in depth from 1 to 5 meters. This species was not collected in the few samples obtained from greater depths.

Collections were made during May, June, and December of 1956. The temperature of the water during the December collections was about 24° C. The temperatures at the collecting sites during May and June ranged from 26.5° to 29.5° C. The salinity of the water was about 37.5 parts per thousand.

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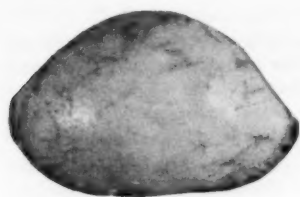
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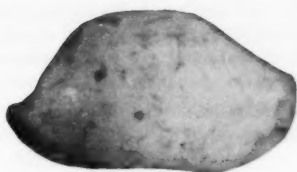
PLATE 1

- 1 *Bairdia harpago* Kornicker, n. sp.
a-b, external views of left and right valves of holotype, specimen no. 122B-12.
- 2 *Bairdia gigacantha* Kornicker, n. sp.
a, dorsal view of specimen no. 247-9-x, with anterior to left; b-c, external views of left and right valves of holotype, specimen no. 247-9-3.
- 3 *Bairdia arostrata* Kornicker, n. sp.
a-b, external views of right and left valves of holotype, specimen no. 92.
- 4 *Bairdia dinochelata* Kornicker, n. sp.
a-b, external views of left and right valves of holotype, specimen no. 500-1; c-d, dorsal view (anterior to right) and anterior view of specimen no. 87-G.
- 5 *Bairdoppilata carinata* Kornicker, n. sp.
a, external view of left valve of a male, specimen no. 122B-9; b-c, external views of right and left valves of holotype, specimen no. 122B-2; d, dorsal view (anterior to left) of a female, specimen no. 92-5306-I; e, dorsal view (anterior to left) of a male, specimen no. 246.

Specimens with similar magnification: 1a-b, 2a-c, 3a-b, 4a-b, 5a-e; 4c-d. Specimen in figure 5b-c was photographed with transmitted light to show distribution of opaque and translucent areas of valves. All photographs were made with 3000 speed polaroid film. Specimens in figures 3a-b and 4b were coated with silver nitrate solution. Hinge line in figures 4c, 4d, 5d, and 5e were retouched.



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1b



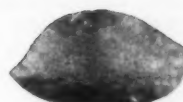
2a



2b



2c



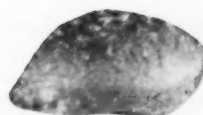
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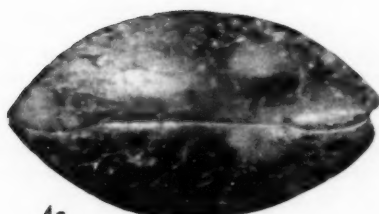
3b



4a



4b

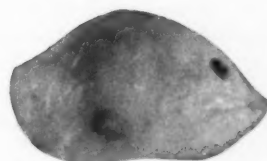


4c

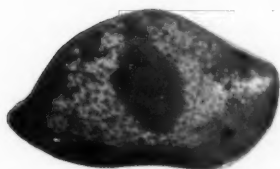
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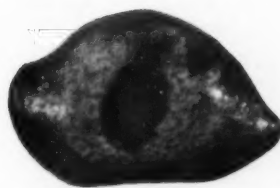
4d



5a



5b



5c



5d



5e

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ABSTRACT Eight megaspore species from Tasmanian and South Australian lower Mesozoic sediments are recorded; six of these are new types. Megaspores referable to *Nathorstisporites hopliticus* Jung which includes those of *Lycostrobus scotti* Nathorst are recorded for the first time from the Southern Hemisphere. Two new species of *Nathorstisporites* and closely associated microspores are described. A new genus, *Banksisporites*, is instituted to include the megaspores previously referred to *Trileites pinguis* (Harris) Polonié and *Duosporites tenuis* (Dijkstra) Piérart. A Rhaetic-Liassic and a Rhaetic age are indicated for the Leigh Creek Coal Measures, South Australia, and the New Town Coal Measures, Tasmania, respectively.

Lower Mesozoic megaspores from Tasmania and South Australia

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INTRODUCTION

The megaspore species described in this paper have been recovered from certain lower Mesozoic sediments from southern Australia. These sediments include coals and associated carbonaceous shales from the New Town Coal Measures, Tasmania and the Leigh Creek Coal Measures, South Australia. The age of the sediments has been regarded by previous authors as Triassic on the basis of the rich and well-preserved macroflora contained in them (Walkom, 1924, 1925; Chapman and Cookson, 1926).

The occurrence of megaspores in these Triassic sediments is of paleobotanical and stratigraphical interest as some of them are identical with or closely related to species described and recorded from the Northern Hemisphere. One type present in the Leigh Creek beds is identical with the form-species *Nathorstisporites hopliticus* Jung and the megaspores of the organ-species *Lycostrobus scotti* Nathorst, recorded previously from Rhaetic and Liassic sediments of Greenland (Harris, T. M., 1926, 1935, 1946) and Europe (Wicher, 1951; Reissinger, 1952; Will, 1953; Znosko, 1955; Lundblad, 1956; Marcinkiewicz, 1957 and Jung, 1958, 1959). Another type occurring in the New Town Coal Measures is included in the form-species *Banksisporites pinguis* (Harris) Dettmann, new comb., which is conformable with the megaspores of the fructification of *Selaginella hallei* (Lundblad) and occurs in Rhaetic strata in Greenland (Harris, T. M., 1935) and Europe (Lundblad, 1950a, 1956; Wicher, 1951; Will, 1953; Marcinkiewicz, 1957; and Jung, 1959). Others are shown to be related to certain Lower Mesozoic species.

Furthermore, the Australian lower Mesozoic megaspore assemblages are quite distinct from those of Middle Jurassic and Lower Cretaceous age recorded from Europe (Murray, 1939; Dijkstra, 1951; Hughes, 1955) and Australia (Cookson and Dettmann, 1958a, 1958b).

They are also distinct from Permian megaspore assemblages described from India (Surange, Singh and Srivastava, 1953; Srivastava, 1954), Brazil (Dijkstra, 1955) and the Belgian Congo (Piérart, 1959).

MATERIAL

The material includes vitreous and dull black coals and associated carbonaceous shales from bores and outcrops near St. Marys, Fingal, Poatina, and Hamilton, Tasmania, and two outcrop samples of grey carbonaceous shales from the Leigh Creek Coalfield, South Australia.

The Tasmanian material is from the New Town Coal Measures or its equivalents (*vide* Mr. M. R. Banks), which contain a flora dominated by *Cladophlebis australis* (Morris), *Johnstonia* spp., *Ginkgoites* spp., *Baiera* spp., *Pterophyllum* spp., *Sphenozamites* spp., and *Otozamites* spp. On this basis, the age of the sediments, is considered to be Rhaetic (Walkom, 1925; Nye and Lewis, 1928; Hills and Carey, 1949). Harris (1937) noted the similarity of the Tasmanian flora to that occurring in the Molteno beds of the Karroo System of South Africa, the age of which is considered to be Middle Triassic (Watson in Townrow, 1957).

The age of the Leigh Creek Coal Measures is based chiefly on the work of Chapman and Cookson (1926) who examined the contained flora and suggested a Triassic age. More recently Wade (1953) recorded the occurrence in these beds of a poorly preserved fish with Triassic affinities. Taylor (1953), in an attempt to correlate the various coal seams within the coalfield, described and figured a number of microspore types which occur in them. However, these microspores have not been given generic or specific status and no attempt has been made to compare the microflora with other lower Mesozoic microfloras. The detailed locations of the sediments are:

Tasmania

1) Cornwall Mine, near St. Marys, bore no. 1 at 97 feet, 486 feet, and 580 feet; bore no. 2, sample nos. 6, 21A (at 406-9 feet), 25A (at 439-40 feet), 28, 29, 30, 32 (at 637-9 feet), and 33 (at 644-6 feet). Concerning Cornwall Mine bore no. 2, in the majority of cases only the sample numbers have been made available but in some cases both the sample number and depth are provided. The samples are numbered consecutively in order of increasing depth.

2) Jubilee Mine, one-half to one mile east of Cornwall Mine, near St. Marys, bore no. 1, at 76 feet, 303 feet, and 340 feet.

3) Langloh, bottom seam.

4) Duncan Colliery, Fingal, samples from top and middle of seam.

5) Barbers Colliery, Fingal, delta seam.

6) Northeastern tip of Great Lake, Hydro-Electricity Commission bore no. 5018 at 461 feet; bore no. 5087 at 424 feet.

South Australia

Leigh Creek Coal Field, Leigh Creek, pale grey shale from northern field (Department of Geology, University of Adelaide registered no. NF 7) and dark grey shale from open cut of northern field (about 138°24'E, 30°24'S).

METHOD

The recovery of the megaspores was by methods similar to the one adopted by Cookson and Dettmann (1958a) and to that of Dijkstra (1955). These methods include disintegration and maceration of the sediment prior to individual sorting of the megaspores from other plant and organic matter.

Following the method of Cookson and Dettmann, approximately 10 grams of each of the shales was dissolved in cold hydrofluoric acid and the residue passed through a 100-mesh (approximately 150 μ -mesh) copper sieve. The material retained on the sieve was placed in a solution of 50 cc. of concentrated nitric acid and 2 to 3 grams of sodium chlorate. After 2 to 3 hours the residue was washed several times with distilled water, 5% potassium hydroxide solution and finally in distilled water. The residue was transferred to water in a petri dish and searched for megaspores under a binocular microscope at a magnification of 35 diameters and the megaspores picked out using a fine camel hair brush.

This method was modified slightly for the coals. Approximately 5 grams of each of the coals was added to a solution of 50 cc. of concentrated nitric acid and 5 grams of sodium chlorate for 12 hours. The residue was washed in distilled water, 5% potassium hydroxide, sieved and searched for megaspores. In addition the coal samples

were treated by a modification of Zetsches' method used by Dijkstra. Five grams of material was macerated in 20 cc. of fuming nitric acid for 3 to 4 hours and the residue washed and sieved before final searching for megaspores.

The megaspores recovered by these methods were suitable for examination in reflected light but were insufficiently translucent for examination in transmitted light. They were cleared by a treatment in either concentrated nitric acid for 1 to 2 days or in clove oil for 10 to 15 minutes. The latter treatment was the more satisfactory because the megaspores were sufficiently cleared without damage to their walls. Opaque specimens are mounted dry in well slides and translucent specimens are mounted in either unstained glycerene jelly or polystyrene.

Microtome sections of specimens were obtained following the embedding and cutting techniques of Waterman (1939, pp. 52-62) and Pantin (1948, pp. viii, 79). The embedding medium, Waterman's wax, is prepared by melting together and filtering through cotton wool, paraffin (M. Pt. 56°C), stearic acid, spermaceti wax and ceresin wax in the ratio by weight 80:16:3:1. The spores were transferred through solutions of 50% alcohol, absolute alcohol, methyl benzoate for 30 minutes, benzene paraffin solution for 15 to 30 minutes and two changes of Waterman's wax for 30 to 40 minutes. The sections were cut at 5 μ intervals, dewaxed in xylene and absolute alcohol and mounted in euparal.

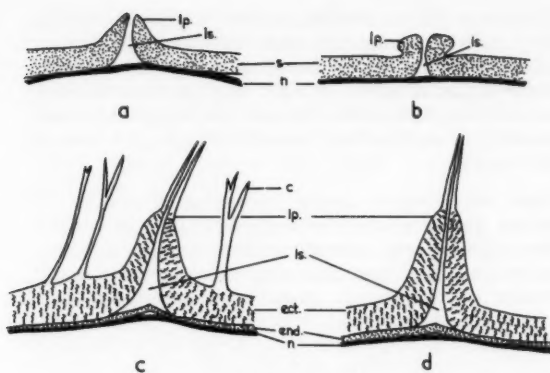
NOTES ON THE SYSTEMATIC DESCRIPTIONS

The system of nomenclature suggested by Potonié (1956, 1958) for form-genera has been followed throughout. The descriptions include the characters observed in the examination of opaque, translucent and, in certain cases, sectioned and dissected specimens. Unless otherwise specified, the polar and equatorial diameters included in the descriptions have been derived from at least 15 examples of both opaque and translucent specimens. The holotypes designated are translucent mounts.

The terminology proposed by Erdtman (1952) for the sclerine stratification of pollen and spores is used herein for megaspores. Although Erdtman has not specifically stated that his terminology is applicable to megaspores, he has used it (1956, 1957) in defining the sclerine stratification of certain megaspores. In the following systematic descriptions Erdtman's terms "exine", "sexine" and "nexine" are applied only to distinguish between the layers of a megaspore wall. It is not intended to imply that the wall layers of megaspores are homologous with those of microspores. Following this nomenclature the terms "sexine" and "nexine" are used instead of the terms "exoexine" and "intexine" which were proposed by Potonié (1952) for the same layers.

Furthermore, accepting the above terminology, the term "mesospore" proposed by Fitting (1900, p. 112) becomes redundant. This author instituted the term for

LOWER MESOZOIC MEGASPORES



TEXT-FIGURE 1

Sections cut transversely to the laesura of the megaspore wall. a) *Banksisporites pinguis* (Harris) Dettmann, comb. nov.; b) *Bacutriteles gyrus* Dettmann, sp. nov.; c) *Nathorstisporites hopliticus* Jung; d) *Nathorstisporites flagellatus* Dettmann, sp. nov.

lp = lip; ls = laesura; s = sexine; ect = ectosexine; end = endosexine; n = nexine; c = capilli.

the middle wall layer of viable megaspores in which the nexine is partially or almost completely separated from the sexine by a cavity. In defining this type of exine construction Faegri and Iversen's term "cavate" is used. This term was erected (1950, p. 160) for pollen in which the ectexine (sexine of Erdtman) is loosened from the endexine (nexine) and W. F. Harris (1955, p. 25) extended its use for spores.

The term "lips" (W. F. Harris 1955, p. 13) is used in defining any modification of the sexine immediately adjoining the dehiscence fissures of the laesurae. As shown in sectioned specimens the lips are upturned or reflexed extensions of the sexine (text-figs. 1-2). In *Banksisporites* the sexine extends to form a low ridge (text-fig. 1a); in *Bacutriteles* the extension of the sexine is reflexed (text-fig. 1b); in *Nathorstisporites* the ectosexine forms the high membranous lips and shows modification in sculpture (text-fig. 1c-d); in *Pyrobolospira* (Hughes, 1955, text-fig. 2) the neck segments which enclose the laesurae are highly elevated, specialized extensions of the ectosexine.

SYSTEMATIC DESCRIPTIONS

Anteturma SPORITES H. Potonié, 1893

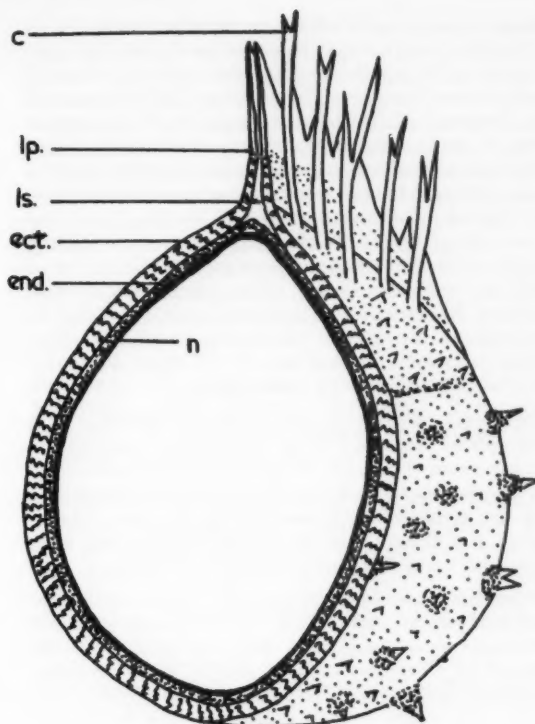
Turma TRILETES (Reinsch, 1881) Potonié and Kremp, 1954

Subturma AZONOTRILETES Luber, 1935

Infraturma LAEVIGATI (Bennie and Kidston, 1886) Potonié 1956

Genus *Banksisporites* Dettmann, new genus

Diagnosis: Megaspores trilete; exine cavate, consisting of nexine (mesospore) and sexine which are detached from each other except in an area about the laesurae.



TEXT-FIGURE 2

Nathorstisporites hopliticus Jung cut through the poles.

c = capilli; lp = lip; ls = laesura; ect = ectosexine; end = endosexine; n = nexine.

Nexine homogeneous or composed of granules; sexine smooth or granular. Laesurae straight or sinuous, with or without lips.

Type species: *Banksisporites pinguis* (Harris) Dettmann, comb. nov.

The generic name is in honour of Mr. M. R. Banks, Department of Geology, University of Tasmania, who kindly provided most of the material for this investigation.

Comments: In being characterized by a cavate exine, *Banksisporites* resembles *Duosporites* (Höeg, Bose and Manum) Höeg and Bose and certain species of *Biharisporites* Potonié and *Hughesisporites* Potonié. However, *Banksisporites* differs from *Duosporites* in the absence of small nipple-like projections on the nexine and from *Biharisporites* and *Hughesisporites* in the character and distribution of the sexine sculpture.

The presence and structure of a freely separating nexine (mesospore) was first recognized by Höeg, Bose and Manum (1955) to be of taxonomic value in the classification of dispersed fossil megaspores. At that time these authors proposed the genus *Duosporites* for "Triradiate megaspores with smooth or nearly smooth surface.

Mesosporium detached from exosporium except in an area on the proximal side. Proximal part of mesosporium provided with nipple-like projections pointing towards the interior of the spore." Later, Piérart (1959) emended this diagnosis of *Duosporites* to include all megaspores with a freely separating nexine (mesospore), irrespective of the nexine structure or sexine sculpture. The species referred by Piérart to *Duosporites* include *Duosporites* (*Triletes*) *endosporitiferus* (Singh) = *Duosporites congoensis* Höeg, Bose and Manum, *Duosporites* (*Triletes*) *trivedii* (Dijkstra) and *Duosporites* (*Triletes*) *tenuis* (Dijkstra). More recently, Höeg and Bose (1960) nullified Piérart's emendation of *Duosporites* and in consequence the species *Duosporites trivedii* and *Duosporites tenuis* are excluded from it. Of these, *Duosporites tenuis* is conformable with *Banksisporites*.

Other fossil megaspores which are conformable with *Banksisporites* include those previously referred to *Trileites pinguis* (Harris), which is herein designated as the type species, those of *Banksisporites sinuosus* Dettmann, new sp., recovered and described during this investigation, and those of the fructifications *Selaginella hallei* (Lundblad) and *Selaginellites polaris* Lundblad.

The species included in *Banksisporites* show a wide geographical distribution. *Banksisporites pinguis* (Harris) Dettmann, new comb., has been recorded from the Rhaetic of Greenland (T. M. Harris, 1935), Sweden (Lundblad, 1950a, 1950b), Germany (Wicher, 1951; Will, 1953; Jung, 1959), Poland (Marcinkiewicz, 1957) and occurs in the Rhaetic sediments of Tasmania. *Banksisporites tenuis* (Dijkstra) Dettmann, new comb., from lower Gondwana sediments of Brazil (Dijkstra, 1955) and the Belgian Congo (Piérart, 1959). *Banksisporites sinuosus* is present in the Rhaetic sediments of Tasmania.

Within the two species, *Banksisporites pinguis* and *Banksisporites sinuosus*, examined in this investigation, there is a wide variation in the characters of the nexine. In small tetrahedral spores the nexine is distinct, turgid and much smaller in radius than the sexine, while in larger biconvex spores the nexine is not always apparent, (usually crumpled or folded), and of radius almost equal to that of the sexine. In view of similar observations made by Fitting (1900) on megaspores of living species of *Isöetes* and *Selaginella* and by Lundblad (1950b) on megaspores of the fructification *Selaginella hallei*, these variants probably represent spores in different stages of maturity rather than different species. However, for more conclusive evidence these variants should be studied by statistical methods and compared more closely with similar megaspores of living species and fossil fructifications.

***Banksisporites pinguis* (Harris) Dettmann,
new combination**

Plate 1, figures 1-8; text-figure 1a

Triletes pinguis HARRIS, 1935, Medded om. Grönl., vol. 112, p. 166, pl. 25, fig. 3; text fig. 52A-D.

Trileites pinguis (Harris). - POTONIE, 1956, Geol. Jahrb., Beih., vol. 23, p. 24.

Description: The Australian spores range from tetrahedral with a triangular amb (immature spores) to biconvex with a circular amb (mature spores). Laesurae ca. $\frac{2}{3}$ radius of spore, straight or slightly undulating, strongly lipped. Lips 30-40 μ high, 10-20 μ broad at pole, tapering gradually, both in width and height, towards the equator.

Exine two-layered, cavate, consisting of nexine and sexine; sexine and nexine adherent only in an area about the laesurae, elsewhere they are separated by a cavity as shown in sectioned specimens (pl. 1, fig. 5). Nexine of tetrahedral spores apparent, 2-4 μ thick, composed of granules, separated from sexine by a comparatively large cavity (pl. 1, fig. 4); of biconvex spores not always visible, ca. 1-2 μ thick, usually crumpled or folded and of radius almost equal to that of the spore (pl. 1, figs. 1-3); of opaque specimens not visible. Nexine bears faint impression of laesurae as seen in dissected specimens (pl. 1, fig. 6).

Sexine 10-25 μ thick, smooth in optical section, finely granular in surface view under oil immersion (LO pattern); forms the elevated lips of the laesurae.

Dimensions: Dry specimens - equatorial diameter 190-530 μ ; polar diameter 190-470 μ . Translucent specimens - equatorial diameter 210-530 μ ; polar diameter 250-410 μ ; equatorial diameter of nexine 140-370 μ .

Occurrence: Tasmania - Cornwall Mine, bore no. 1 at 97 feet, 486 feet, and 580 feet, and bore no. 2 sample nos. 6, 21A (at 406-9 feet), 28, and 33 (at 644-6 feet); HydroElectricity Commission bore no. 5087 at 424 feet.

Comments: The Australian representatives of *Banksisporites pinguis* (more than 100 specimens have been examined) show a wider variation in size, shape and character of the nexine than the twelve specimens described by T. M. Harris (1935) from Greenland. However, similar variations in this species have been described in examples recorded from Sweden which are conformable with megaspores, possibly representing different stages of maturity, of *Selaginella hallei* (Lundblad, 1950a, 1950b).

Banksisporites pinguis differs from the other species in this genus in the nature of the straight or slightly undulating, lipped laesurae. It is of common occurrence in the Tasmanian coals but has not been observed in the Leigh Creek sediments.

***Banksisporites sinuosus* Dettmann, new species**
Plate 1, figures 9-14

Description: Megaspores tetrahedral to biconvex with a triangular to circular amb. Laesurae sinuous, lipped, ca. $\frac{2}{3}$ radius of spore. Lips sinuous, 8-20 μ broad and 15-40 μ high at pole; straightening and tapering, both in width and height, towards equator. Lips of tetrahedral spores more prominent but less sinuous than those of biconvex spores.

LOWER MESOZOIC MEGASPORES

Exine two-layered, consisting of nexine and sexine which are adherent to each other only along the laesurae, otherwise they are separated by a cavity. Nexine of tetrahedral spores (pl. 1, figs. 12–13) apparent, $\frac{2}{3}$ radius of spore, composed of granules, 2–4 μ thick; of biconvex spores (pl. 1, figs. 9–11) rarely evident, ca. 1–2 μ thick, usually folded. Nexine not visible in opaque dry specimens.

Sexine 10–20 μ thick, granular both in optical section and surface view, forms the elevated lips of the laesurae. In some tetrahedral spores the sexine of the contact faces is slightly undulating.

Dimensions: Dry specimens – equatorial diameter 190–504 μ ; polar diameter 190–420 μ . Translucent specimens – equatorial diameter 260–540 μ ; polar diameter 250–480 μ ; equatorial diameter of nexine 150–320 μ .

Holotype: Geology Department, University of Tasmania, registered no. 54591 (pl. 1, fig. 11). Megaspore with circular amb, equatorial diameter 385 μ . Laesurae 110 μ long, sinuous, lipped; lips 8–10 μ broad. Sexine 12 μ thick, granular; nexine thin, folded.

Locus typicus: Tasmania – Cornwall Mine bore no. 1 at 580 feet.

Occurrence: Tasmania – Cornwall Mine, bore no. 1 at 97 feet, 486 feet, and 580 feet, and bore no. 2 sample nos. 6, 21A (at 406–9 feet), 28, 32 (at 637–9 feet), and 33 (644–6 feet); Hydro-Electricity Commission bore no. 5087 at 424 feet; Duncan Colliery, top and middle of seam; Langloh, bottom seam; Barbers Colliery, delta seam.

Comments: The 100 specimens examined show a considerable variation in size, shape, prominence of lips and nexine character. Some of these specimens show a very close resemblance to the figured specimens of *Banksisporites* (*Duosporites*) *tenuis* (Dijkstra) recovered from Permian sediments of Belgian Congo (Piérart, 1959, pl. 3, fig. 5; pl. 5, fig. 1). M. P. Piérart, who examined specimens of *Banksisporites sinuosus*, has kindly informed me that, in having a smaller size range and a granular exine, *Banksisporites sinuosus* is not conformable with *Banksisporites tenuis* (the size range of the latter species is 400–1,000 μ).

Infraturma APICULATI (Bennie and Kidston, 1886)
Potonié, 1956

Genus BACUTRILETES (van der Hammen, 1954) Potonié, 1956

***Bacutritiletes gyrys* Dettmann, new species**

Plate 2, figures 2–7; text-figure 1b

Description: Megaspores baculate, biconvex, circular to subtriangular in equatorial outline, elliptical or occasionally circular in polar outline. Laesurae straight, conspicuously lipped, ca. $\frac{2}{3}$ radius of spore. Lips reflexed, forming broad (12–18 μ wide), elevated (20–30 μ high), flat-topped ridges.

Exine 15–20 μ thick, consists of homogeneous nexine ca. 1–2 μ thick, and finely granular sexine 13–19 μ thick, which forms the reflexed lips of the laesurae, the conspicuous baculae of the equatorial region and distal surface and the smaller baculae of the contact faces. Baculae twice as long as broad, infragranulate, appear transversely striate due to a regular arrangements of the granules. On the contact faces the baculae, if present, are inconspicuous (6–8 μ long and 3–5 μ broad) and sparsely arranged; on the remainder of the spore they are larger, (16–50 μ long and 10–20 μ broad), and randomly arranged 8–20 μ apart, except at the lower margin of the contact faces where they occur in a well-defined, dense ring.

Dimensions: Dry specimens – equatorial diameter 400–530 μ ; polar diameter 430–500 μ . Translucent specimens – equatorial diameter 440–700 μ ; polar diameter 500–600 μ .

Holotype: Geology Department, University of Tasmania, registered no. 54592, (pl. 2, fig. 2). Megaspore with subtriangular amb, equatorial diameter 440 μ . Laesurae 165 μ long, lipped; lips 17 μ broad. Sexine 14 μ thick, nexine ca. 2 μ thick. Baculae 12–16 μ broad, 20–25 μ long, restricted to equatorial region and distal surface of spore.

Locus typicus: Tasmania – Hydro-Electricity Commission bore no. 5018 at 461 feet.

Comments: This species resembles *Bacutritiletes tylosus* (Harris) and *Bacutritiletes greenlandicus* (Miner), but is readily distinguishable by the nature and distribution of the baculae. The baculae of *Bacutritiletes tylosus* and *Bacutritiletes greenlandicus* are equally developed and almost evenly distributed over the entire surface of the spore, whereas in *Bacutritiletes gyrys* Dettmann, new sp., the baculae on the contact faces are smaller and more sparsely distributed than those on the remainder of the spore.

Bacutritiletes gyrys is of rare occurrence and has been recovered from only one deposit.

Infraturma MURORNATI Potonié and Kremp, 1954
Genus HORSTISPORITES Potonié, 1956

***Horstisporites microlumenus* Dettmann, new species**

Plate 2, figures 8–13

Description: Megaspores tetrahedral to biconvex, circular to sub-triangular or occasionally polygonal in polar view, flattened elliptical in equatorial view. Laesurae straight, $\frac{2}{3}$ radius of spore, simple or lipped; lips, if present, inconspicuous, in the form of low (up to 25 μ high), narrow (6 μ broad), incised ridges which are highest and widest at the pole.

Exine reticulate, consists of two layers; a homogeneous nexine ca. 1–2 μ thick and a granular, 11–30 μ thick

sexine which forms the lips of the laesurae and the imperfect surface reticulum. The irregularly-meshed reticulum of the sexine consists of low (2–6 μ high), narrow (2–4 μ wide), muri which terminate freely or coalesce to form circular or polygonal lumen 7–18 μ in diameter (pl. 2, fig. 13). The muri are broadest at their bases, tapering sharply towards their crests and in optical section appear as sharp, spinose projections (pl. 2, fig. 12). The reticulum of dry opaque specimens is not always discernable at low magnifications.

Dimensions: Dry specimens – equatorial diameter 270–580 μ ; polar diameter (two specimens) 350 μ , 420 μ . Translucent specimens – equatorial diameter 250–600 μ ; polar diameter, no specimens available.

Holotype: Geology Department, University of Tasmania, registered no. 54593 (pl. 2, fig. 8). Megaspore with circular amb, equatorial diameter 550 μ . Laesurae 187 μ long, lipped; lips 23 μ high, 4 μ broad. Exine 25 μ thick, reticulate; muri 4 μ wide, 6 μ high, enclosing polygonal to circular lumen 11–15 μ in diameter.

Locus typicus: Tasmania – Hydro-Electricity Commission bore no. 5087 at 424 feet.

Occurrence: Tasmania – Cornwall Mine, bore no. 1 at 97 feet, and 580 feet, and bore no. 2 sample nos. 6, 25A (at 439–40 feet), 29, 30, 32 (at 637–9 feet), and 33 (at 644–6 feet); Jubilee bore at 340 feet; Hydro-Electricity Commission bore no. 5087 at 424 feet.

Comments: This species is similar to *Horstisporites harrisi* (Murray) in having an imperfect reticulum, but differs in the smaller-meshed reticulum.

Horstisporites microlumenus Dettmann, n. sp., occurs in relatively small numbers in the majority of the sediments examined.

Turina BARBATES Mädlar, 1954
Genus HUGHESISPORITES Potonié, 1956

***Hughesisporites variabilis* Dettman, new species**
Plate 1, figures 15–20; Plate 2, figure 1

Description: Megaspores tetrahedral with a subtriangular amb (immature spores) to biconvex with an almost circular amb (mature spores). Laesurae lipped, sinuous or rarely straight, $\frac{2}{3}$ radius of spore. Lips 20–45 μ high, 8–20 μ broad, more sinuous at pole than towards equator.

Exine two-layered, cavate; sexine attached to nexine in an area on the proximal surface. Nexine of small tetrahedral spores (pl. 1, figs. 17–20) $\frac{2}{3}$ radius of spore, turgid, composed of granules, 4–6 μ thick of biconvex spores (pl. 1, figs. 15–16) homogeneous in structure, ca. 1–2 μ thick, usually crumpled or folded; of opaque dry specimens not visible.

Sexine 8–20 μ thick, finely granular, forms a conspicuous sculpture pattern on the contact faces; sculpture pattern comprised of raised elevations which are

variable in width, height and length. In tetrahedral spores the elevations are broad-based (12–20 μ), prominent (up to 20 μ high), closely spaced verrucae; in biconvex spores the elevations are elongate (30–100 μ long, 6–20 μ broad, up to 20 μ high), widely spaced, radially arranged, sinuous or straight rugulae which sometimes anastomose to form a coarse-meshed, irregular reticulum. Other specimens show sculpture patterns intermediate between these.

Dimensions: Dry specimens – equatorial diameter 200–420 μ ; polar diameter 240–390 μ . Translucent specimens – equatorial diameter 200–500 μ ; polar diameter 230–400 μ ; equatorial diameter of nexine 130–310 μ .

Holotype: Geology Department, University of Tasmania, registered no. 54594 (pl. 1, fig. 15). Megaspore with circular amb, equatorial diameter 437 μ . Laesurae 143 μ long, lipped; lips sinuous, 8 μ broad. Sexine 17 μ thick, granular and with rugulae on the contact faces; rugulae sinuous, 17 μ broad, 69 μ long, radiating from pole. Nexine thin, folded.

Locus typicus: Tasmania – Cornwall Mine, bore no. 2 at 644–6 feet.

Occurrence: Tasmania – Cornwall Mine, bore no. 1 at 486 feet, and 580 feet, and bore no. 2 sample nos. 32 (at 637–9 feet), and 33 (at 644–6 feet); Jubilee bore at 76 feet, and 303 feet; Hydro-Electricity Commission bore no. 5087 at 424 feet.

Comments: This species is a broad type and includes spores which are probably in different stages of maturity. Although resembling *Banksisporites* in the nature of the cavate exine, it has been referred to *Hughesisporites* on account of the sexine sculpture. Some specimens of *Hughesisporites variabilis* show a striking resemblance to the figured specimen of *Hughesisporites ionthus* (Harris) (T. M. Harris, 1935, pl. 26, fig. 8), but differ in having a cavate exine and in the absence of a ridge demarking the lower margin of the contact faces.

It occurs in abundant numbers in the Tasmanian coals but has not been observed in the Leigh Creek samples.

Genus NATHORSTISPORITES Jung, 1958

***Nathorstisporites hopliticus* Jung, 1958**
Plate 3, figures 1–5; text-figures 1c, 2

Description: The Australian megaspores included in this species consist of a spheroidal spore body with a sub-circular amb, and conspicuous deeply incised, elevated lips which enclose and obscure the laesurae.

Exine consists of a homogeneous nexine ca. 2 μ thick, and a two-layered sexine (pl. 1, fig. 5); sexine may separate from nexine in overmacerated spores. Endosexine 2–4 μ thick, composed of randomly arranged granules; ectosexine 18–28 μ thick, granular, of porous structure and forms the conspicuous lips, the larger and smaller broad-based spines and the almost straight-

LOWER MESOZOIC MEGASPORES

sided, branched capilli. Larger spines 20–30 μ long, composed of a wartlike base which is itself granular and 15–20 μ in diameter, and a smooth-surfaced, sharply pointed tip; evenly distributed over spore surface 50 μ apart, except adjacent to laesurae. Smaller spines with a smooth surface, 6 μ broad at base, 6 μ long, scattered between larger spines. Capilli 10–15 μ broad, as much as 150 μ long, smooth, dichotomously branched, restricted to contact faces and more densely arranged around laesurae.

Lips consist of a granular base, 15–20 μ wide, and an upper smooth membrane which is deeply incised and occasionally perforated; $\frac{1}{2}$ radius of spore, higher at pole (up to 150 μ) than towards equator. Contact faces delimited by a low sexinous elevation which runs parallel to the equator.

Dimensions: Dry specimens – equatorial diameter 300–540 μ ; polar diameter 340–480 μ . Translucent specimens – equatorial diameter 350–650 μ ; polar diameter 380–580 μ .

Occurrence: South Australia – Leigh Creek Coalfield, dark grey shale from open cut of northern field (about 138°24'E, 30°24'S).

Comments: *Nathorstisporites hopliticus* includes dispersed megaspores conformable with those of the fructification *Lycostrobus scotti* Nathorst; Dr. B. Lundblad who examined some of the Australian examples is of the opinion that they are closely similar to *Lycostrobus scotti* megaspores. The megaspores have been previously recorded from Rhaetic and Liassic sediments of Greenland (T. M. Harris, 1926, 1935, 1946), Sweden (Lundblad, 1956), Germany (Wicher, 1951; Reissinger, 1952; Will, 1953; and Jung, 1958, 1959) and Poland (Znosko, 1955; and Marcinkiewicz 1957). This record of *Nathorstisporites hopliticus* from South Australia indicates that it has a wide geographical distribution in lower Mesozoic sediments.

Nathorstisporites reticulatus Dettmann, new species

Plate 3, figures 6–9

Description: Megaspores consisting of an almost spherical spore body with a reticulate surface and considerably elevated, fringelike lips.

Exine composed of a sculptured sexine 8–10 μ thick, and homogeneous nexine ca. 1–2 μ thick; sexine and nexine separate from each other in spores subjected to prolonged maceration. Sexine two-layered; endosexine ca. 2 μ thick, composed of randomly arranged granules; ectosexine granular, forms the surface reticulum, proximal capilli and elevated lips of the laesurae. Surface reticulum inconspicuous with low (2–3 μ high), narrow (5–10 μ wide) muri and polygonal lumen 10 μ in diameter. Reticulum of contact faces smaller meshed and with lower muri than that of the remainder of the spore. Capilli smooth, 150 μ long, 8–10 μ wide, almost straight-sided, simple or more often, dichotomously branched

with hooked apices; restricted to and densely arranged on contact faces; often entangled with one another and with the lips. Contact faces delimited by a low sexinous elevation which runs parallel to the equator.

Lips 120–200 μ high, appear homogeneous in structure, heavily perforated and deeply dissected; obscuring laesurae and extending almost to equator.

Dimensions: Dry specimen – equatorial diameter 480 μ ; polar diameter 425 μ . Translucent specimens – equatorial diameter (6 specimens) 300–440 μ ; polar diameter (3 specimens) 300–350 μ .

Holotype: National Museum of Victoria paleontological collection, no. P 17822 (pl. 3, figs. 7, 9). Megaspore with almost spherical spore body 439 μ in diameter. Lips 154 μ high, 230 μ long, deeply incised. Exine 11 μ thick, reticulate; muri 2 μ high, 10 μ wide, enclosing polygonal lumen 10 μ in diameter.

Locus typicus: South Australia – Leigh Creek Coalfield, dark grey shale from open cut of northern field (about 138°24'E, 30°24'S).

Occurrence: Tasmania – Cornwall Mine bore no. 1 at 580 feet; Hydro-Electricity Commission bore no. 5087 at 424 feet. South Australia – Leigh Creek Coalfield, dark grey shale from open cut of northern field (about 138°24'E, 30°24'S).

Comments: This species is represented by eight specimens which differ from *Nathorstisporites hopliticus* and *Nathorstisporites peltaticus* Jung in the nature of the sexinous sculpture and the more deeply dissected lips of the laesurae.

Associated microspores: Specimens of monolete microspores are present amongst the lips and capilli of the holotype (pl. 3, fig. 9) and other examples of *Nathorstisporites reticulatus*. Microspores closely similar to these (pl. 3, fig. 10) are of common occurrence in all the samples from which *Nathorstisporites reticulatus* has been recovered; however, only the microspores associated with the megaspores are described.

Description: Microspores monolete with an elliptical amb. Laesura almost as long as the long axis of spore. Exine ca. 1–2 μ thick, granulate both in optical section and surface view; granules sparsely arranged.

Dimensions: (10 specimens) length 28–37 μ , breadth 19–28 μ .

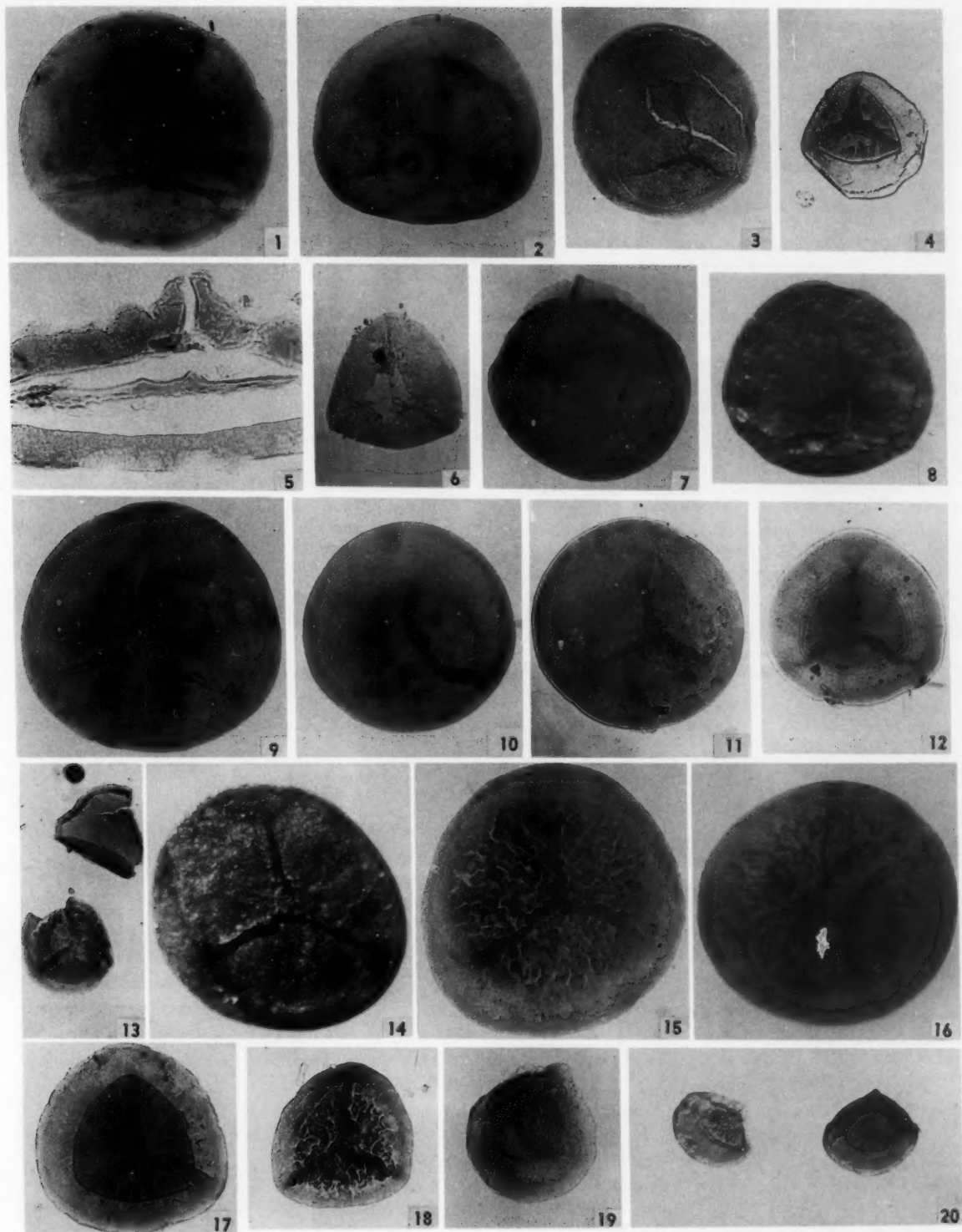
Comments: These spores are conformable with those described by Jung (1958) which occur in close association with *Nathorstisporites hopliticus* and *Nathorstisporites peltaticus*. Jung considers that the microspores in having a granular exine are conformable with the Paleozoic form-genus *Punctatosporites* Potonié and those of *Lycostrobus scotti* described by Nathorst (1908). However, according to Nilsson (1958), *Lycostrobus scotti* microspores show a punctate rather than a granular exine.

DETTMANN

PLATE 1

All photographs are from unretouched negatives and, unless otherwise stated, were taken in transmitted light and at a magnification of 100 diameters. The letter "P" preceding a number indicates that the specimen has been deposited in the paleontological collection of the National Museum of Victoria, Melbourne. The letter "T" preceding a number indicates that the specimen has been deposited in the Geology Department, University of Tasmania. All other photographed specimens have been deposited in the paleontological collection of the National Museum of Victoria, Melbourne.

- 1 *Banksisporites pinguis* (Harris) Dettmann, comb. nov.
Biconvex spore in which the nexine is not apparent. Tasmania, Hydro-Electricity Commission bore no. 5087 at 424 feet.
- 2 *Banksisporites pinguis* (Harris) Dettmann, comb. nov.
Biconvex spore in which the nexine is evident but folded. Tasmania, Cornwall Mine, bore no. 1. at 580 feet.
- 3 *Banksisporites pinguis* (Harris) Dettmann, comb. nov.
Specimen showing the thin walled nexine which is folded. Tasmania, Cornwall Mine, bore no. 1 at 97 feet.
- 4 *Banksisporites pinguis* (Harris) Dettmann, comb. nov.
Tetrahedral spore in which the thick-walled nexine is clearly evident. Tasmania, Hydro-Electricity Commission bore no. 5087 at 424 feet.
- 5-6 *Banksisporites pinguis* (Harris) Dettmann, comb. nov.
5, Microtome section of specimen cut transversely to the equator and through the laesura showing the cavate nature of the exine, $\times 400$; 6, nexine of dissected specimen showing faint impression of laesurae on the proximal surface. Both from Tasmania, Hydro-Electricity Commission bore no. 5087 at 424 feet.
- 7 *Banksisporites pinguis* (Harris) Dettmann, comb. nov.
Equatorial view of specimen showing the nexine and elevated lips of the laesurae. Tasmania, Cornwall Mine, bore no. 2 at 644-6 feet.
- 8 *Banksisporites pinguis* (Harris) Dettmann, comb. nov.
Proximal view of specimen in reflected light. Tasmania, Cornwall Mine, bore no. 1 at 580 feet.
- 9-10 *Banksisporites sinuosus* Dettmann, sp. nov.
Proximal views of paratypes in which the nexine is not evident. 9, Tasmania, Cornwall Mine, bore no. 2 sample no. 28; 10, Tasmania, Cornwall Mine, bore no. 2 at 637-9 feet.
- 11 *Banksisporites sinuosus* Dettmann, sp. nov.
Proximal view of holotype, T. 54591, showing folded nexine. Tasmania, Cornwall Mine, bore no. 1 at 486 feet.
- 12 *Banksisporites sinuosus* Dettmann, sp. nov.
Proximal view of tetrahedral paratype showing the turgid nexine. Tasmania, Cornwall Mine, bore no. 2 at 406-9 feet.
- 13 *Banksisporites sinuosus* Dettmann, sp. nov.
Distal view of specimen prior to mounting and from which portion of the distal sexine has been dissected, $\times 50$. Tasmania, Cornwall Mine, bore no. 2 at 637-9 feet.
- 14 *Banksisporites sinuosus* Dettmann, sp. nov.
Proximal view of paratype in reflected light. Tasmania, Cornwall Mine, bore no. 1 at 580 feet.
- 15 *Hughesisporites variabilis* Dettmann, sp. nov.
Holotype, T. 54594, showing folded nexine and the radially arranged rugulae of the sexine. Tasmania, Cornwall Mine, bore no. 2 at 644-6 feet.
- 16 *Hughesisporites variabilis* Dettmann, sp. nov.
Paratype showing rugulate sexine and in which the nexine is not evident. Tasmania, Cornwall Mine, bore no. 1 at 580 feet.
- 17-19 *Hughesisporites variabilis* Dettmann, sp. nov.
Proximal and equatorial views of tetrahedral paratypes showing the densely arranged verrucae of the proximal surface and in which the nexine is evident. 18, Tasmania, Cornwall Mine, bore no. 2 at 644-6 feet; 17, 19, Tasmania, Hydro-Electricity Commission bore no. 5087 at 424 feet.
- 20 *Hughesisporites variabilis* Dettmann, sp. nov.
Oblique view of specimen $\times 50$, from which portion of the sexine has been dissected. Tasmania, Hydro-Electricity Commission bore no. 5087 at 424 feet.



The occurrence of microspores, conformable with those described by Jung in association with *Nathorstisporites reticulatus* not only suggests that these megaspores are derived from a heterosporous plant bearing trilete megaspores and monolete microspores, but also that they are closely related to *Nathorstisporites hopliticus* and *Nathorstisporites pellaticus*. Further evidence for this relationship is provided by the close morphological and almost identical structural agreement between *Nathorstisporites reticulatus* and *Nathorstisporites hopliticus*.

***Nathorstisporites flagellulatus* Dettmann,
new species**

Plate 3, figures 11–12; Plate 4, figures 1–9; text-figure 1d

Description: Megaspores consisting of a biconvex spore body with a circular amb and elevated, incised lips which enclose the laesurae.

Exine composed of homogeneous nexine ca. 1–2 μ thick and a sculptured two-layered sexine; nexine separates from sexine in spores subjected to prolonged maceration. Endosexine 2 μ thick, composed of granules; ectosexine 12–35 μ thick, granulate, of porous structure and forms large spinelike processes, small conical spines and the incised lips. Spinelike processes consist of a granular base of porous structure, (31–52 μ wide, 40–100 μ high), and a longer (70–160 μ), smooth, homogeneous, tapering

portion which narrows gradually to form a hooked or whiplike tip (pl. 4, fig. 9). Processes branched, restricted to and densely arranged ca. 70 μ apart on distal surface; usually broken except on well-preserved specimens. Small conical spines smooth, 7–10 μ long, 5–7 μ broad at base, occur on both distal and proximal surface.

Lips 80–350 μ high, extend to margin of spore; consist of a granular base 20 μ thick, 50–120 μ high and an upper thin, smooth, homogeneous portion 30–200 μ high, which is deeply and irregularly incised.

Dimensions: Dry specimens – equatorial diameter 510–1,020 μ ; polar diameter 300–800 μ . Translucent specimens – equatorial diameter 600–1,000 μ ; polar diameter 500–800 μ .

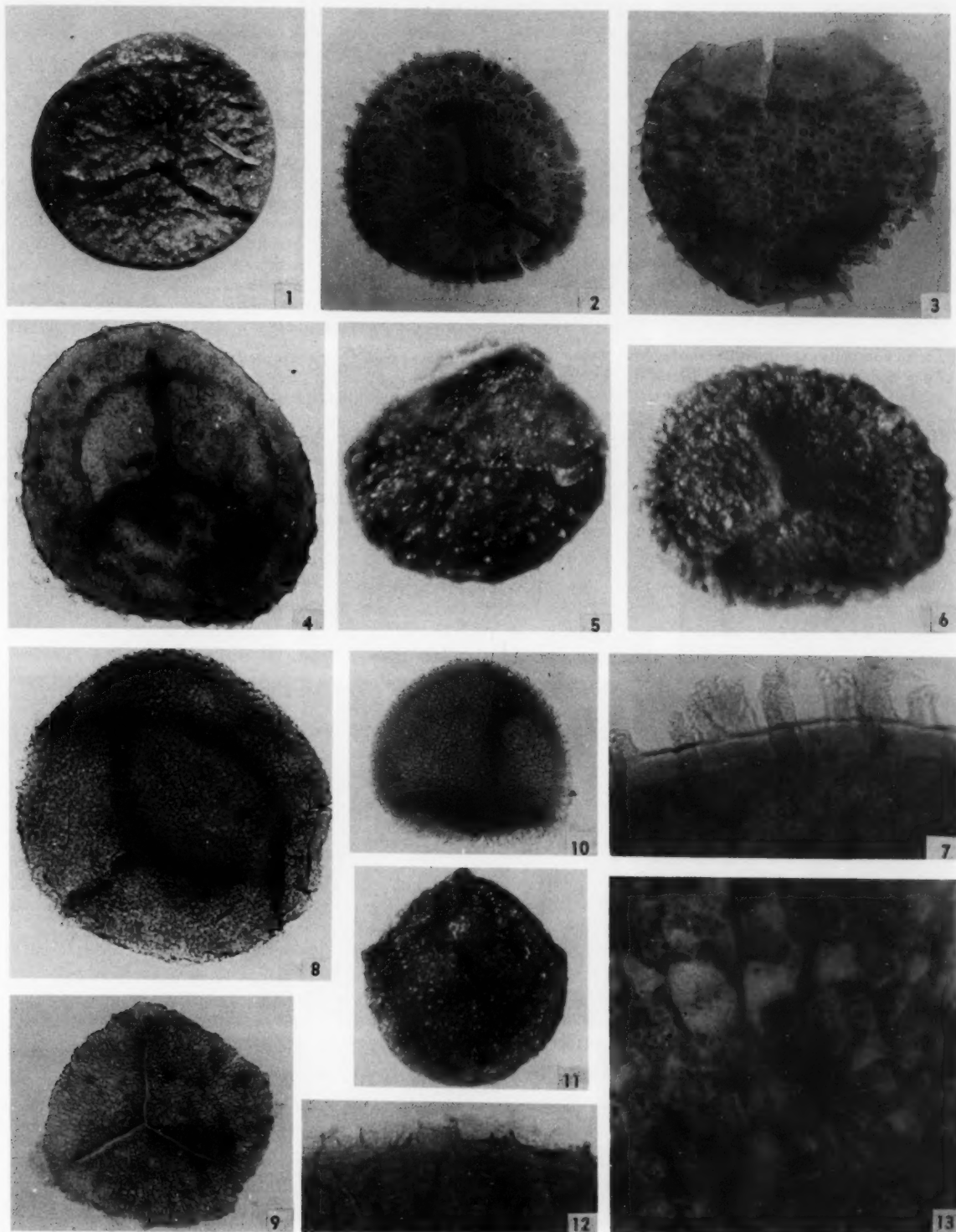
Holotype: Geology Department, University of Tasmania, registered no. 54595 (pl. 4, fig. 1). Megaspore biconvex with circular amb 930 μ diameter. Lips 470 μ long, 120 μ high, deeply incised. Exine 30 μ thick; large spines 200 μ long, 62 μ broad at base; small spines 8 μ long, 6 μ broad.

Locus typicus: Tasmania – Cornwall Mine bore no. 1 at 580 feet.

Occurrence: Tasmania – Cornwall Mine bore no. 1 at 580 feet, and bore no. 2 sample nos. 6, 21A (at 406–9 feet), 28, 29, 30, and 32 (at 637–9 feet); Hydro-Electricity Commission bore no. 5087 at 424 feet.

PLATE 2

- 1 *Hughesisporites variabilis* Dettmann, sp. nov.
Polar view of paratype in reflected light. Tasmania, Cornwall Mine, bore no. 1 at 580 feet.
- 2 *Bacutriteles gyrus* Dettmann, sp. nov.
Proximal view of holotype, T. 54592. Tasmania, Hydro-Electricity Commission bore no. 5018 at 461 feet.
- 3–4 *Bacutriteles gyrus* Dettmann, sp. nov.
Paratypes, equatorial and polar views. Tasmania, Hydro-Electricity Commission bore no. 5018 at 461 feet.
- 5–6 *Bacutriteles gyrus* Dettmann, sp. nov.
Paratypes, equatorial and polar views in reflected light. Tasmania, Hydro-Electricity Commission bore no. 5018 at 461 feet.
- 7 *Bacutriteles gyrus* Dettmann, sp. nov.
Optical section of exine of holotype \times 400, showing baculae.
- 8 *Horstisporites microlumenus* Dettmann, sp. nov.
Holotype, T. 54593, proximal view. Tasmania, Hydro-Electricity Commission bore no. 5087 at 424 feet.
- 9 *Horstisporites microlumenus* Dettmann, sp. nov.
Proximal view of paratype. Tasmania, Cornwall Mine, bore no. 1 at 580 feet.
- 10 *Horstisporites microlumenus* Dettmann, sp. nov.
Tetrahedral paratype showing the conspicuous lips of the laesurae. Tasmania, Cornwall Mine, bore no. 2 at 644–6 feet.
- 11 *Horstisporites microlumenus* Dettmann, sp. nov.
Equatorial view of paratype in reflected light. Tasmania, Hydro-Electricity Commission bore no. 5087 at 424 feet.
- 12–13 *Horstisporites microlumenus* Dettmann, sp. nov.
12, Optical section of exine showing the sharply tapering muri of the surface reticulum \times 400; 13, surface view of exine showing the imperfect surface reticulum \times 600.



Comments: *Nathorstisporites flagellulatus* Dettmann, new sp., is readily distinguishable from other species of *Nathorstisporites* by the large spinelike processes. It is of common occurrence in the Tasmanian sediments.

***Nathorstisporites* sp.**

Plate 4, figure 10

A single specimen of a spore undoubtedly conformable with *Nathorstisporites* was recovered from the pale grey shale from northern field, Leigh Creek Coalfield, South Australia.

Megaspore consisting of a compressed spore body, which is circular in equatorial view, and has elevated, membranous lips which show a smooth surface and are deeply incised. Lips 77μ high, extend almost to equator.

Exine comprises nexine and two-layered sexine. Nexine homogeneous, ca. 1μ thick, partially detached from sexine; endosexine 8μ thick, appears homogeneous in structure; ectosexine 14μ thick, infragranular and with irregularly branched, smooth capilli densely arranged in an area around the lips. Capilli 8μ broad at base, 65μ high.

Dimensions: Translucent specimen – equatorial diameter 580μ ; polar diameter 540μ .

Specimen no.: National Museum of Victoria paleontological collection no. P17824.

Comments: In the absence of sexinous sculpture on the distal surface, this specimen is distinct from known species of *Nathorstisporites*.

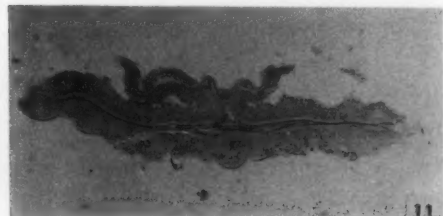
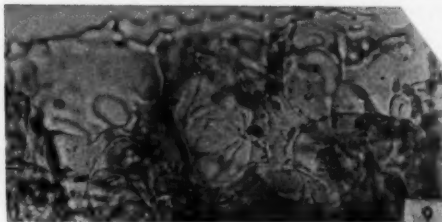
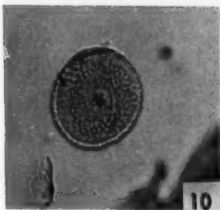
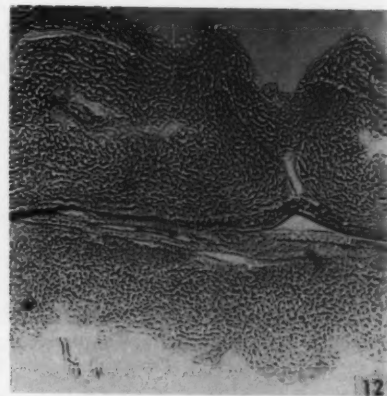
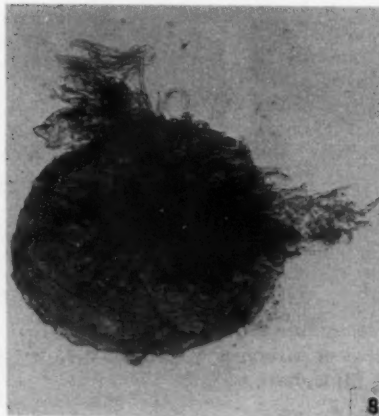
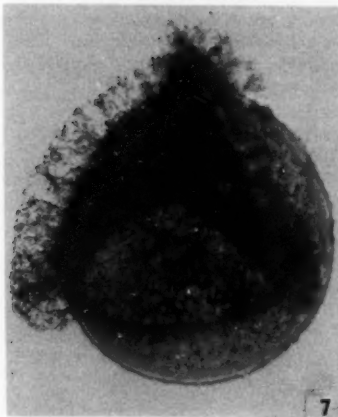
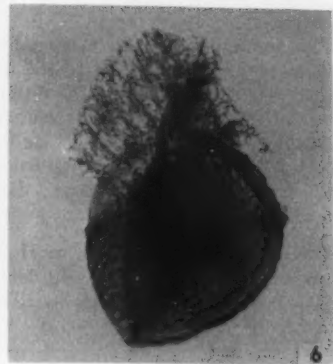
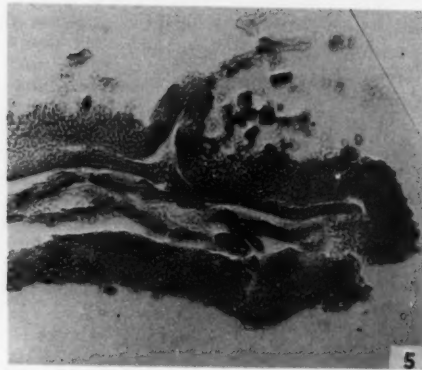
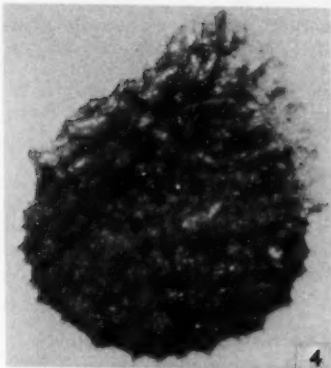
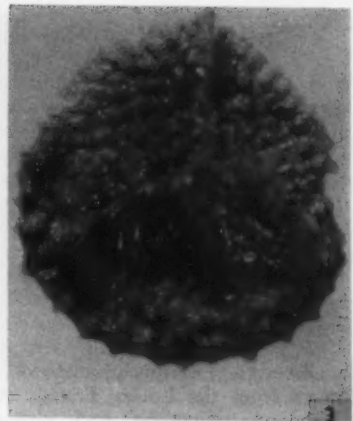
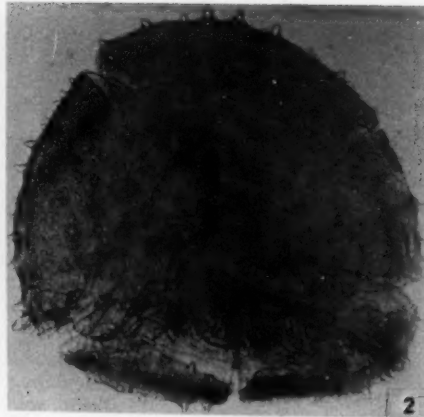
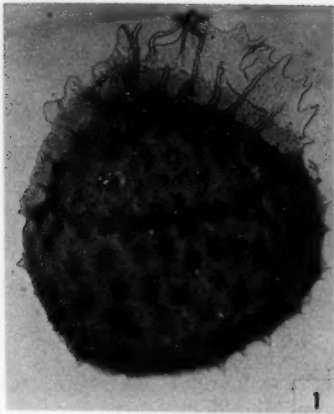
CONCLUSION

Two lower Mesozoic megaspore assemblages are distinguished in the Australian deposits. One, which is dominated by *Nathorstisporites hopliticus*, occurs in the Leigh Creek deposit, and the other, which is characterized by *Banksisporites pinguis* and *Nathorstisporites flagellulatus* is present in the majority of the samples taken from the New Town Coal Measures, Tasmania. The occurrence in these sediments of either *Nathorstisporites hopliticus* or *Banksisporites pinguis* provides a means of correlation between lower Mesozoic strata of the Northern Hemisphere and Australia.

The Leigh Creek sample from the open cut of northern field containing *Nathorstisporites hopliticus* is correlated with uppermost Rhaetic and lower Liassic strata of East Greenland ("transitional bed" and "*Thaumatopteris* zone" of Scoresby Sound), Sweden and Germany and Lower Liassic sediments of Poland. On this basis the age of the Leigh Creek deposit is considered to be Rhaetic-Liassic, a determination more precise than the Triassic age suggested by Chapman and Cookson (1926). The other megaspores recovered from the Leigh Creek samples include *Nathorstisporites reticulatus* and *Nathorstisporites* sp., which are new types.

PLATE 3

- 1–2 *Nathorstisporites hopliticus* Jung
Equatorial and proximal views. South Australia, Leigh Creek Coalfield, dark grey shale from open cut of northern field.
- 3–4 *Nathorstisporites hopliticus* Jung
Proximal and equatorial views in reflected light. South Australia, Leigh Creek Coalfield, dark grey shale from open cut of northern field.
- 5 *Nathorstisporites hopliticus* Jung
Microtome section of overmacerated specimen $\times 400$, cut transversely to the equator showing nexine, endosexine and ectosexine which forms the lips of the laesurae.
- 6, 8 *Nathorstisporites reticulatus* Dettmann, sp. nov.
Equatorial views of paratypes. 6, South Australia, Leigh Creek Coalfield, dark grey shale from open cut of northern field; 8, Tasmania, Hydro-Electricity Commission bore no. 5087 at 424 feet.
- 7 *Nathorstisporites reticulatus* Dettmann, sp. nov.
Holotype, P17822, proximal view showing the deeply incised lips of the laesurae. Leigh Creek Coalfield, dark grey shale from open cut of northern field.
- 9 Monolet microspores amongst the lips of the holotype of *Nathorstisporites reticulatus* Dettmann, sp. nov.; $\times 500$.
- 10 Polar view of dispersed microspore conformable with those associated with *Nathorstisporites reticulatus* Dettmann, sp. nov.; $\times 500$, South Australia, Leigh Creek Coalfield, dark grey shale from open cut of northern field.
- 11–12 *Nathorstisporites flagellulatus* Dettmann, sp. nov.
Microtome section of specimen cut through the poles and transversely to the equator. 11, $\times 100$; 12, $\times 400$, showing nexine, endosexine and porous ectosexine which forms the lips of the laesurae.



The Tasmanian deposits taken from Cornwall Mine bore no. 1 at 580 feet and Hydro-Electricity Commission bore no. 5087 at 424 feet contain a megaspore assemblage which includes the following species: *Banksisporites pinguis*, *Banksisporites sinuosus*, *Horstisporites microlumenus*, *Hughesisporites variabilis*, *Nathorstisporites reticulatus* and *Nathorstisporites flagellulatus*. Of these, *Banksisporites pinguis* occurs in Rhaetic sediments of East Greenland ("Lepidopteris zone" of Scoresby Sound), Sweden, Germany and Poland. Its occurrence in the New Town Coal Measures of Tasmania supports the accepted Rhaetic age of the sediments. However, a pre-Rhaetic age must not be overlooked, as Lundblad (1959, p. 92) has clearly stated that *Banksisporites pinguis*, in resembling the megaspores of *Selaginellites polaris* known from the Lower Triassic (Eotriassic) of East Greenland, "must be used with discrimination for stratigraphical work".

The remainder of the megaspore-containing samples taken from the New Town Coal Measures of Tasmania (except that from Hydro-Electricity Commission bore no. 5018 at 461 feet) have yielded one or more of the species found in Cornwall Mine bore no. 1 at 580 feet and Hydro-Electricity Commission bore no. 5087 at 424 feet. It is probable that all these sediments are of a similar age.

The core sample taken from Hydro-Electricity Commission bore no. 5018 at 461 feet contains *Bacutritiles gyrus* but none of the other species have been observed in it.

ACKNOWLEDGEMENTS

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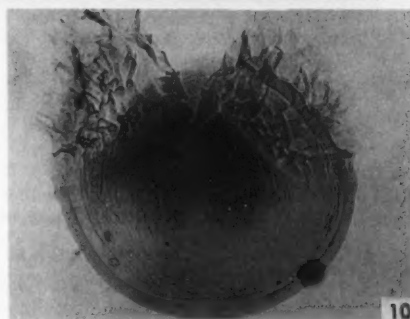
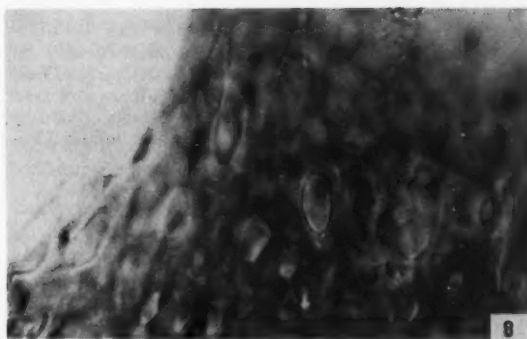
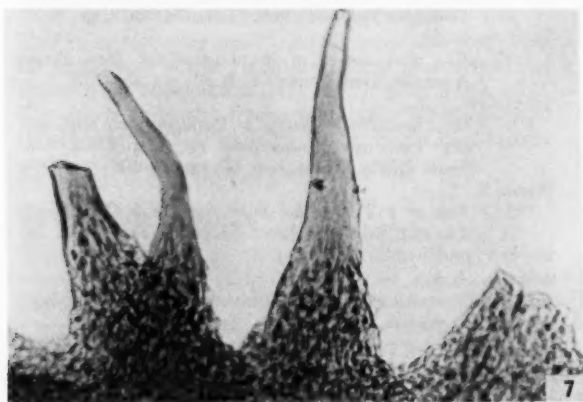
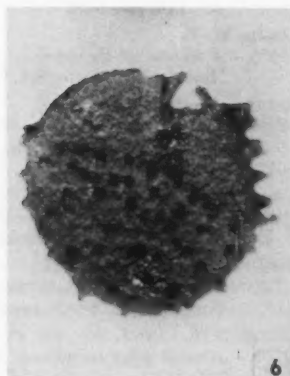
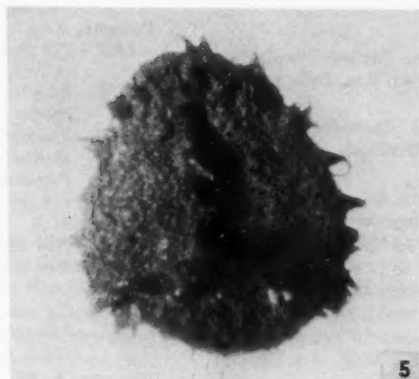
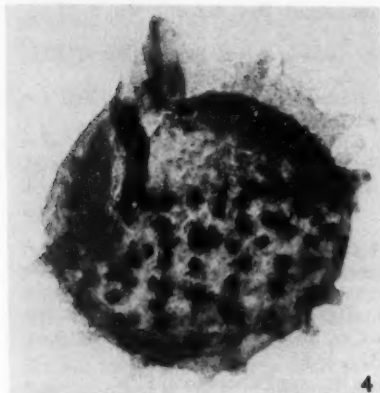
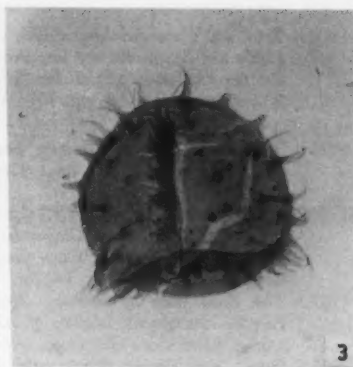
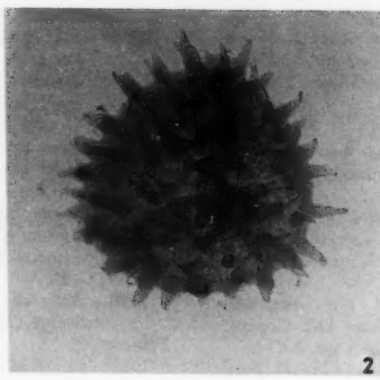
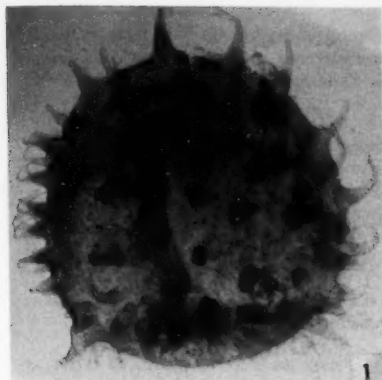
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PLATE 4

- 1 *Nathorstisporites flagellulatus* Dettmann, sp. nov.
Proximal view of holotype, T. 54595, $\times 50$. Tasmania, Cornwall Mine, bore no. 1 at 580 feet.
- 2-4 *Nathorstisporites flagellulatus* Dettmann, sp. nov.
Distal, proximal and equatorial views of paratypes $\times 50$. 2 and 4, Tasmania, Cornwall Mine, bore no. 1 at 580 feet; 3, Tasmania, Cornwall Mine, bore no. 2 at 637-9 feet.
- 5-6 *Nathorstisporites flagellulatus* Dettmann, sp. nov.
Proximal and equatorial views of paratypes in reflected light $\times 50$. Tasmania, Cornwall Mine, bore no. 1 at 580 feet.
- 7-8 *Nathorstisporites flagellulatus* Dettmann, sp. nov.
Surface views of exine. 7, showing broken spine-like processes $\times 400$; 8, showing porous nature of ectosexine and small spines $\times ca. 1300$.
- 9 *Nathorstisporites flagellulatus* Dettmann, sp. nov.
Fragment of exine showing unbroken spine-like processes $\times 300$.
- 10 *Nathorstisporites* sp.
P17824, equatorial view. South Australia, Leigh Creek, pale grey shale from northern field.



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ABSTRACT *Diatoms and associated acid-insoluble microscopic forms from the Recent sediments of the fresh-water tanks and the mangrove swamps of the Bengal Delta are described and illustrated.*

Recent microscopic flora from the Bengal Delta, India

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INTRODUCTION

A few sediment samples of Recent age from the southern part of the Bengal Delta were examined. The samples are distributed into two broad groups; the estuarine river mud of the Sunderbans, and bottom mud of the fresh-water ponds of Calcutta and Garia. Interesting diatom tests obtained from these samples are described. Brief mention is made of some of the pollen and spores that occur associated in the diatom preparations.

The estuarine river mud samples were collected from the confluence of the Thakuran, Matla and Bidyadhari rivers in the Sunderbans (text-fig. 1), in October, 1957. The muds from the fresh-water tanks were collected throughout 1958-1959 from the environs of Calcutta and Garia.

THE SUNDERBAN MICROFLORA

The name Sunderban comes from "Sundri" (*Heritiera minor*) and "ban" (forest). It is also known as the Sunderban mangrove swamp because of the thick and varied mangrove vegetation and other halophytic vegetation in its southern seaside stretches. There are numerous tidal rivers and creeks in the Sunderbans. The waters of these rivers and creeks are saline owing to daily tides from the Bay of Bengal. Freshwater vegetation cannot grow in these tidal swamps. During the high tides the halophytes are partially submerged, but they are exposed to the air during the low tides. Halophytic vegetation, which is especially adapted to the saline water and daily tidal wash, is typical of this region (Prain, 1903). These forms have aerial breathing roots. Some, such as *Aegialitis rotundifolia*, are adapted to heavy intake of salt water and to excessive evaporation. Others, such as *Phoenix paludosa* and *Acanthus ilicifolius*, have developed xero-

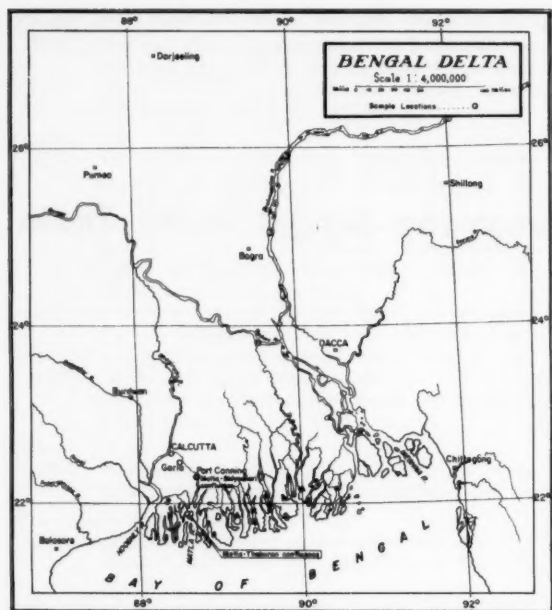
phytic adaptations. Gravity sorting of the seeds by water currents prior to germination may possibly account for their gregarious nature. The dispersal of the seeds takes place immediately after the monsoons. Sedges grow abundantly on the banks of the tidal rivers.

Mangroves are halophytes in which saplings grow on the mother plant before beginning individual existence, an adaptation against failure to germinate in salt water (vivipary of the Rhizophoraceae). The rivers of the west Bengal Sunderbans are more saline than those of the adjoining areas to the east in Pakistan. More vigorous growth of the halophytes in East Pakistan is a well-known phenomenon.

Diatoms of the family Coscinodisceae are very abundant in these samples. It is especially interesting to note the occurrence of several species of the typically marine genus *Coscinodiscus*. Most of these species from the marine waters of the Madras Coast have already been described and figured by Subrahmanyam (1946). The marine genus *Pyxidicula* of the subfamily Melosirineae also occurs in these samples. None of these diatoms can exist in fresh water.

Other genera of associated diatoms are *Cyclotella* of the subfamily Melosirineae, *Cocconeis* of the subfamily Cocconeideae and *Pleurosigma* of the subfamily Naviculaceae. These may occur in fresh water, brackish water, or in sea water. Members of the Naviculaceae are rather rare in these samples.

It should be emphasized that many marine diatoms described from the open marine waters of the Madras Coast by Subrahmanyam (1946) do not occur in these



TEXT-FIGURE 1

samples. The diatom population from these Sunderban samples is peculiar in that it has an admixture of some genera that usually occur in fresh water and others which can exist only in salt water. Just as the Sunderban has a halophytic vegetation peculiar to its own, it has a diatom microflora that is distinctive. It has not been possible to study the seasonal fluctuation of diatom populations from these waters.

Other forms obtained from these samples are some pollen of the halophytic vegetation, some pollen from the mangroves, some spores of marshy ferns (abundant), some Cyperaceae fruits, some microforaminifera, and rare floated conifer pollen.

MICROSCOPIC FLORA FROM FRESH-WATER PONDS

The southern part of the Bengal Delta is located in the tropical to subtropical monsoon forest belt. However, cultivated vegetation has seriously interfered with the natural vegetational distribution in these areas.

Diatoms of the subfamilies Melosirineae and Naviculaeae have been found in the bottom mud of ponds between Calcutta and Garia (text-fig. 1). The species found are typical of fresh-water diatom populations. The record of diatoms from fresh-water ponds is very incomplete, but agrees quite well with the fresh-water occurrence of diatoms.

Other forms found in these samples are pollen of aquatic and marshy dicotyledons and rare fern spores that are well-known in the Bengal Delta.

DESCRIPTION OF DIATOMS

Coscinodiscus excentricus Ehrenberg Plate 1, figure 1

Discoidal, outline circular; areolae hexagonal, arranged in eccentric series (oblique tangential), nine to twelve in 10 microns; center undifferentiated; periphery striated; zones none; apparently concentric when epitheca and hypotheca are in articulation; habitat brackish and cosmopolitan marine.

Coscinodiscus rothii (Ehr.) Grunow var. *subsalsa* (Juhlil-Dannfelt) Hust. Plate 1, figure 2

Discoidal, outline circular; areolae hexagonal, ten in 10 microns, nearly uniform in size, arranged in slightly oblique intersecting tangential series; peripheral margin 6 microns across, with spines; zones none; diameter 45 microns; habitat, common in sea water and river mouths of the east coast of India.

Coscinodiscus marginatus Ehrenberg Plate 1, figures 3, 12

Discoidal, outline circular; areolae rounded with clear inner chamber opening, three to six in 10 microns; periphery striated, but perhaps not as heavily as the Madras forms of Subrahmanyam (1946); center undifferentiated; zones none; diameter 55–67 microns; habitat brackish, marine cosmopolitan.

Coscinodiscus sp. Plate 1, figure 4

Discoidal, circular-polygonal outline; areolae hexagonal, arranged in radial subequal zones; periphery without border but the radial areolae irregular; no concentric zonation; diameter 68–70 microns; habitat, brackish water of Sunderbans; specific identification could not be made as this species is unreported from India.

Coscinodiscus sp. Plate 1, figure 5

Discoidal, outline circular; areolae very small, of the nature of fine punctations, outline hexagonal, arranged radially; center not differentiated; peripheral margin striated, 3–4 microns wide; diameter 70 microns; habitat brackish, possibly marine; comparable species not described from India.

Coscinodiscus jonesianus (Grev.) Osten? Plate 1, figure 13

Discoidal, outline circular; areolae coarse, irregular polygonal in outline, four to five in 10 microns (away from the periphery); center with tendency to differentiate; zones, radial and spiral rows of areolae; periphery slightly spinose; diameter 140 microns; habitat brackish, marine; cone-shaped processes near the margin characteristic of this species not seen, possibly due to the nature of preservation.

RECENT MICROFLORA FROM BENGAL DELTA

***Cyclotella striata* (Kut.) Grunow**

Plate 1, figures 6-7

Discoidal, outline circular; striae numerous, fine, very closely spaced, radial, traceable up to 20 microns from the periphery, but becoming too fine from then on; center coarsely punctate, with plexus; periphery, zonation concentric, striated outer zone and an apparently smooth central zone; diameter 72 microns (fig. 6), very large compared to the coastal forms of the species reported from India; another specimen (fig. 7), 25 microns in diameter, is difficult to identify between *Cyclotella striata* and *Cyclotella meneghiniana* of authors.

***Pyxidicula minuta* Grunow**

Plate 1, figure 8

Discoidal; outline circular; areolae hexagonal, nine to ten in 10 microns, arranged in two linear systems, intersecting with each other at approximately 45°, periphery with a narrow border along the articulation of the frustules; center undifferentiated; no concentric zonation; diameter 14-15 microns; habitat brackish water in the Sunderbans; reported from Franz Josef Land by Subrahmanyam (1946).

***Pleurosigma* sp.**

Plate 1, figure 11

Frustule elongate-elliptical; subacutely rounded at the poles; raphe rather broad, gently sigmoidal, eccentric; areolae two oblique intersecting sets, forming rounded "areolar" appearance; striae closely spaced, transapically prominent, longitudinal striae less prominent and apparently localized; 88×35 microns; does not compare with described species, but has affinity with *Pleurosigma aestuarii*.

***Cocconeis* sp.**

Plate 1, figure 9

Elliptical; raphe broad and apparently uniform in articulated frustules; striae 18 rows in all, seven in 10 microns measured longitudinally; transapical measurements 33×21 microns; does not compare with any described Indian fresh-water or marine species.

***Melosira sulcata* (Ehr.) Kutz. Hust.**

Plate 1, figure 10

Discoidal, outline circular with dentation; periphery with papillate structures at the border; center undifferentiated; central zone concentric with periphery; 20 microns in diameter, with numerous chromatophores; diameter 34 microns; habitat brackish water.

***Thalassiosira* sp.**

Plate 1, figure 14

Discoidal, outline circular; smooth; periphery slightly thickened; diameter 50 microns.

***Pyxidicula?* sp.**

Plate 1, figure 15

Discoidal, outline circular in valve view; areolae reticulate but difficult to measure in oblique compression; long diameter 23 microns.

DESCRIPTION OF POLLEN SPORES

Fungal spore

Plate 2, figure 18

Uniseriate; five chambers; chamber measurements 8×11 microns.

Fungal spore

Plate 2, figure 19

Uniseriate; five chambers; measurements of the chambers 11×18 microns.

Fern spore

Plate 2, figure 21

Deltoid, trilete, rays nearly reaching the periphery; exine smooth; long diameter 44 microns.

Fern spore

Plate 2, figure 20

Deltoid, trilete, rays fine, nearly reaching the periphery; sides conspicuously concave, exine very thin and smooth; long diameter 35 microns.

Polypodiaceae spore

Plate 2, figure 22

Germinating apparatus not visible but obviously monolet; exine with short, widely spaced spines; differentiation between exospore and endospore not sharp; measurements 36×24 microns.

Pinus sp.

Plate 2, figure 24

Cap 90×62 microns, distinctly granular exine, rim 7 microns, bladders nearly spherical, contracted at the base, 66×52 microns; does not grow or flower when cultivated in the Bengal Delta; drifted by wind either from the Shillong Plateau region or from the Himalayas.

Rhizophora pollen

Plate 2, figure 25

Subprolate, tricolporate with wide transverse furrow, 18×14 microns; habitat, brackish-water mangrove swamps.

Avicennia sp.

Plate 2, figure 26

Prolate, tricolporate, pores inconspicuous in the equatorial compression; exine finely reticulate; 39×18 microns; habitat exclusively brackish water; widely distributed.

Hibiscus tiliaceus

Plate 2, figure 27

Spherical, 90 microns; exine thick, finely granular; long spines 16–20 microns; polyforate, foramina 8 microns in diameter; habitat, common in slightly brackish-water to fresh-water conditions.

Gramineae pollen

Plate 2, figure 28

Broadly elliptical; faintly granular; germinating aperture a single elongated pore; 39×29 microns; habitat, not known if entirely restricted to brackish water or otherwise.

Phoenix paludosa

Plate 2, figure 29

Exine thin, faintly spinose, comparable to *Phoenix sylvestris*; monocolpate, colpi running from pole to pole; 23×14 microns; habitat exclusively brackish water; flowering time November–December.

Bruguiera parviflora

Plate 2, figure 30

Oblate; tricolporate, pores prominent; long diameter 19 microns; habitat, typically brackish water.

Finlaysonia obovata

Plate 2, figure 31

United in tetrads; exine very thin, nearly smooth; long diameter of individual grains about 28 microns; habitat, brackish water.

Clerodendron inerme

Plate 2, figure 32

Tricolporate; exine faintly reticulate; diameter 59 microns; habitat, brackish to nearly fresh water.

Casuarina equisetifolia

Plate 2, figure 33

Tricolporate; exine faintly granular; polar diameter 23 microns; habitat brackish water and salt water; very common in sandy beaches.

DESCRIPTION OF FRESH WATER MICROFLORA

Cyclotella meneghiniana Kutzing

Plate 1, figure 16

Discoidal, outline circular; peripheral zone with radial striations, 5 microns in length; no differentiation of the center; diameter 19 microns; habitat fresh water; occurs also in brackish and salt water; striations of the fresh-water forms apparently shorter than those of the marine forms, as reported by Gandhi (1958) and Subrahmanyam (1946).

Surirella sp.

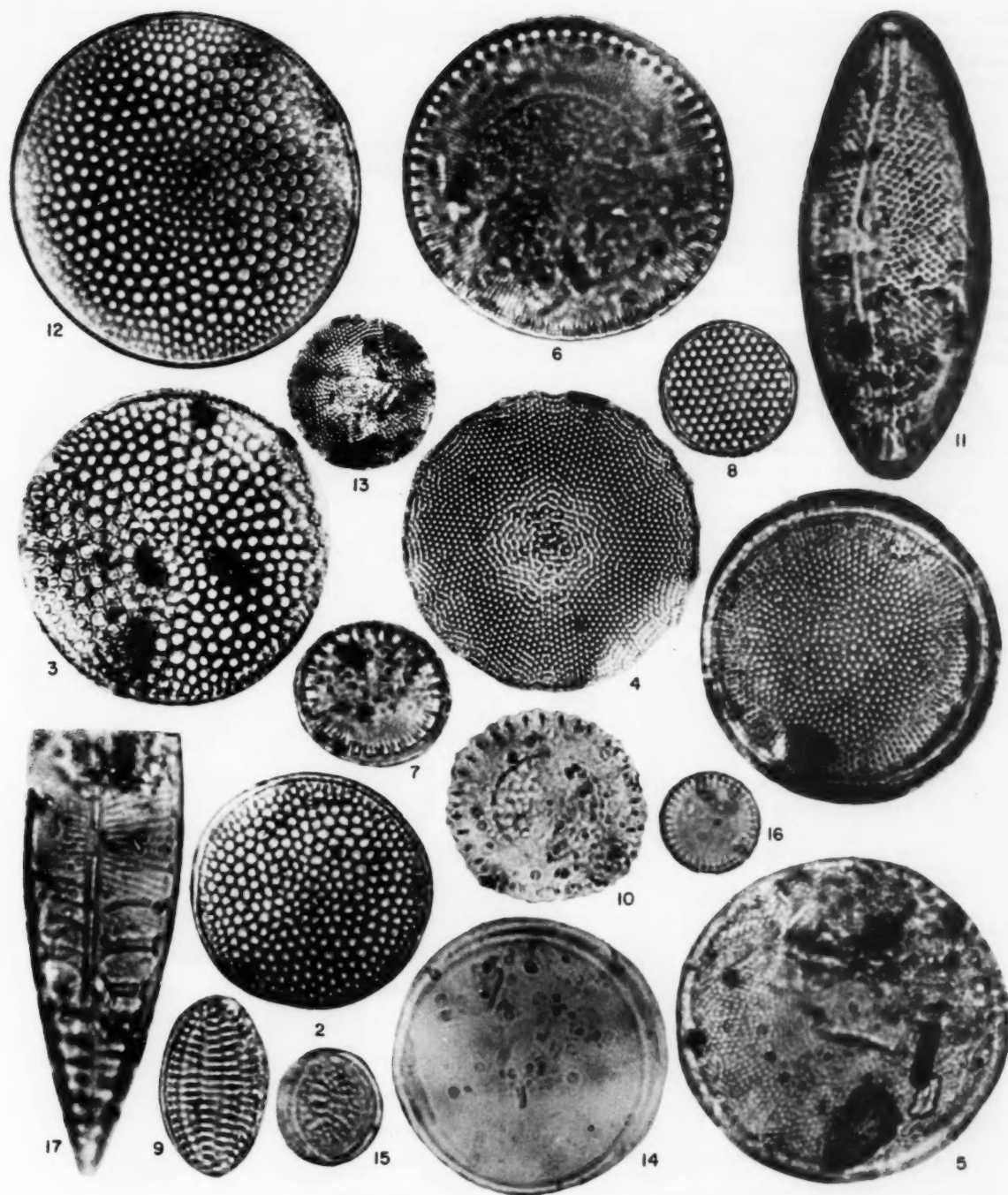
Plate 1, figure 17

Lanceolate; ribs or canaliculi fourteen pairs in one-half of the specimen, broad in the central portion, narrow near the poles; striations fine, oblique-transverse striations along the central part only; one-half the diameter of the specimen 58 microns; habitat, fresh water; not known if range extends to brackish water.

PLATE 1

Figures 1–15 from Sunderbans mangrove swamp samples; figures 16–17 from fresh water. All except figure 13 are magnified approximately 635 diameters.

- | | |
|--|---|
| 1 <i>Coscinodiscus excentricus</i> Ehrenberg, valve view. | 10 <i>Melosira sulcata</i> , valve view. |
| 2 <i>Coscinodiscus rothii</i> (Ehr.) Grunow var. <i>subsalsa</i> (Juh.-Dann.) Hust., valve view. | 11 <i>Pleurosigma</i> sp., girdle view. |
| 3 <i>Coscinodiscus marginatus</i> Ehrenberg, valve view. | 12 <i>Coscinodiscus marginatus</i> Ehrenberg, valve view. |
| 4 <i>Coscinodiscus</i> sp., valve view. | 13 <i>Coscinodiscus jonesianus</i> (Grev.) Ostenfeld?, valve view, 136 diameters. |
| 5 <i>Coscinodiscus</i> sp., valve view. | 14 <i>Thalassiosira</i> sp., valve view. |
| 6–7 <i>Cyclotella striata</i> (Kut.) Grunow, valve view. | 15 ? <i>Pyxidicula</i> sp. |
| 8 <i>Pyxidicula minuta</i> Grunow, valve view. | 16 <i>Cyclotella meneghiniana</i> Kutzing, valve view. |
| 9 <i>Cocconeis</i> sp., girdle view. | 17 <i>Suriella</i> sp., girdle view. |



Colocasia antiquorum

Plate 2, figure 34

Exine thick, typically spinose; spine broad basally, sharply pointed, 3-4 microns long; monosulcate, sulcus parallel to the equatorial plane and peripheral; diameter 28-40 microns; habitat, fresh-water marsh.

Aschynemone asper

Plate 2, figure 25

Tricolpate; exine nearly smooth; 23×13 microns; habitat, fresh-water aquatic.

Typhonium trilobatum

Plate 2, figure 36

Exine moderately thick; with minute spines; definite suggestion of a sulcus, peripheral and parallel to the equatorial plane; diameter 19 microns; common in fresh-water marshes.

Rhoeo discolor

Plate 2, figure 37

Prolate; monosulcate, sulcus extending from pole to pole; exine moderately thick; nearly smooth; 41×16 microns; habitat, fresh-water aquatic.

Hygrophila spinosa

Plate 2, figure 38

Hexacolpate, with three pores; shape nearly spherical, hence grains seldom with perfect polar or equatorial compression; exine faintly reticulate; diameter 35 microns; habitat, fresh-water marshes.

Monochoria hastaeifolia

Plate 2, figure 39

Trisulcate; exine very faintly granular; largest observed diameter 51 microns; habitat, fresh-water marshes.

Sesamum indicum

Plate 2, figure 40

Eleven colpi; the exine with granular structure; diameter 70 microns; habitat, fresh-water marshes.

***Amaranthus* sp.**

Plate 2, figure 41

Spherical, polyporate; 16 microns in diameter; exine details not clear, but rather thick; habitat, several species of the genus common around fresh-water marshes.

Trapa natans

Plate 2, figure 42

Tricolpate; three meridional outer exine flanges; 58×55 microns including the flanges; habitat, fresh-water plankton.

Pandanus tectorius

Plate 2, figure 43

Exine faintly spinose; most of the grains without apparent pores or colpi; only a few grains reveal ulceroid pore; common in fresh-water marshes.

PLATE 2

Figures 18-33 are from Sunderban mangrove swamp samples; figures 34-43 are from fresh-water marsh. All are magnified approximately 635 diameters.

18-19 Fungal spores.

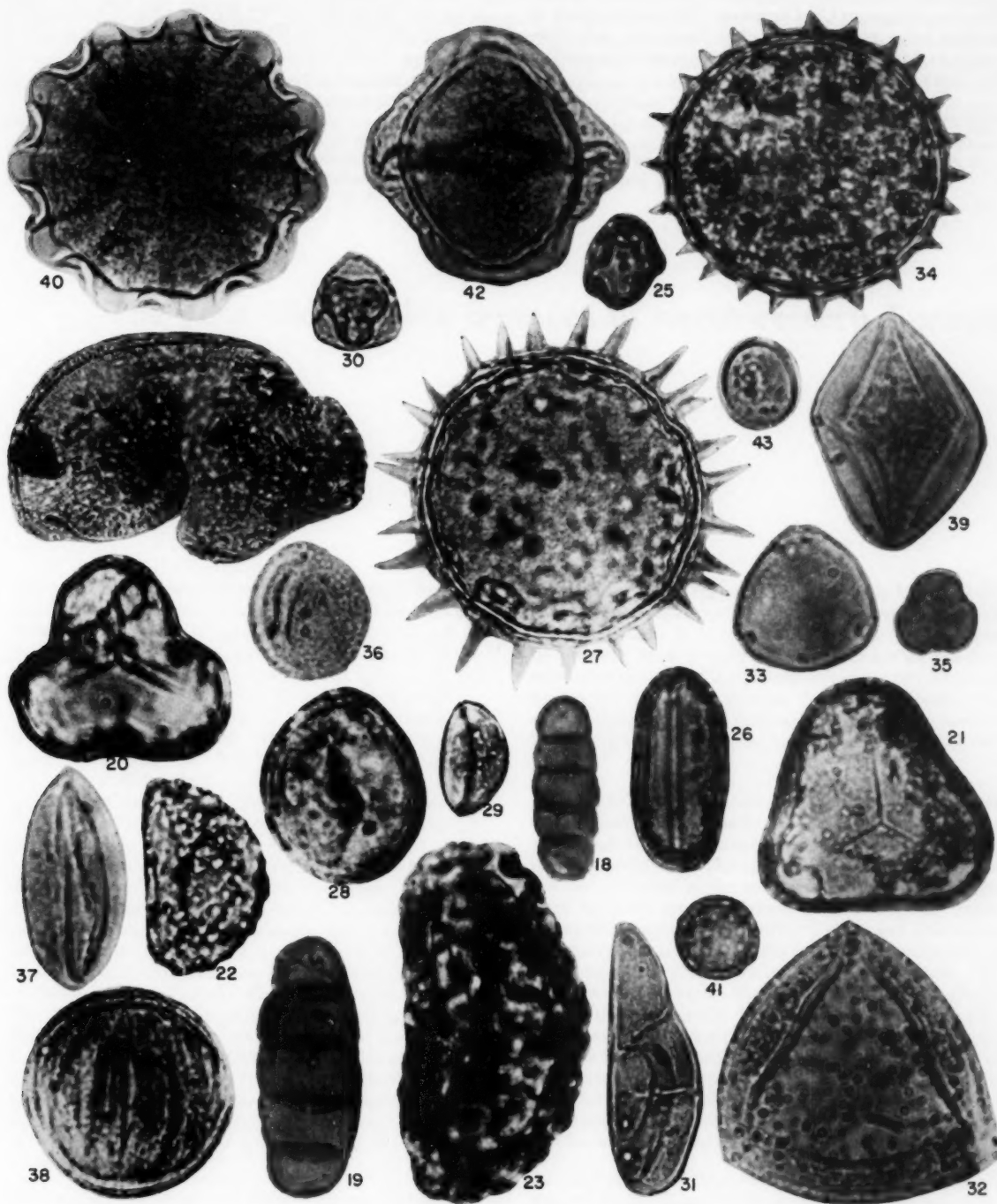
20-21 Fern spores.

22-23 Polypodiaceae spores.

24 *Pinus* sp., ventral compression.25 *Rhizophora* pollen, equatorial compression.26 *Avicennia* pollen, equatorial compression.27 *Hibiscus tiliaceus*.

28 Gramineae pollen.

29 *Phoenix paludosa*, equatorial compression.30 *Bruguiera parviflora*, polar compression.31 *Finlaysonia obovata*, tetrad.32 *Clerodendron inerme*, polar compression.33 *Casuarina equisetifolia*, polar compression.34 *Colocasia antiquorum*, polar compression.35 *Aschynemone asper*, polar compression.36 *Typhonium trilobatum*, polar compression.37 *Rhoeo discolor*, equatorial compression.38 *Hygrophila spinosa*, oblique-polar compression.39 *Monochoria hastaeifolia*.40 *Sesamum indicum*, polar compression.41 *Amaranthus* sp.42 *Trapa natans*.43 *Pandanus tectorius*.



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ABSTRACT *Globigerina cretacea* d'Orbigny, described by d'Orbigny in 1840 as the only trochoid *Globigerina* from the Craie blanche of the Paris Basin, began its development in the Aptian-Albian with the form *Praeglobotruncana infracretacea* (Glaessner); it gradually changed (by enlargement and by change in apertural conditions) into *Praeglobotruncana* sp. cf. *P. gautierensis* (Bronnimann) of Bolli, and occurs in the Cenomanian as *P. crassa* Bolli. Due to the enlargement of the later chambers, the apertural conditions changed gradually, and the developmental stage of typical *Globigerina cretacea* d'Orbigny was reached, beginning in the Turonian. At the end of the Maestrichtian, aberrant forms appeared, of which *Rugoglobigerina rugosa* (Plummer) is the most common. Since a single biological unit ("gens") passes through three different "genera," at least two of them (*Praeglobotruncana* and *Rugoglobigerina*) must be regarded as artificial. This can also be said of the different "species." The gradual change is illustrated by figures of the different stages, as well as by statistical diagrams.

The gens *Globigerina cretacea* in northwestern Europe

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Globigerina cretacea was described and figured for the first time by d'Orbigny in 1840 from the Craie blanche of the Paris Basin; d'Orbigny's figure (1840, p. 34, pl. 3, figs. 12-14) is a poor one, and his description mentions only the distinct umbilicus and the flat spiral side. In the Craie blanche of Meudon, France, only two globigerines can be found, both of which were described very accurately by Marie (1941, p. 235, *Globigerina aspera* Ehrenberg; p. 234, *G. cretacea* d'Orbigny). *G. cretacea* is distinctly trochoidal, although with a flat spire in the Craie blanche, with a large umbilical cavity covered partly by tena protruding from the umbilical chamber walls, an interiomarginal to umbilical aperture, a distinctly pustulose surface, and a strong rounded margin. This is not quite like the poor figure given by d'Orbigny, and therefore that figure has caused much confusion. This confusion is clearly shown in a recent paper by Bolli (1959, p. 270, pl. 22, figs. 8-9), in which a species totally different from the only trochoid species of *Globigerina* found in the Craie blanche of the Paris Basin is figured as *Globigerina cretacea*. The figure does show some similarity to the figure (but not the description) given by d'Orbigny. Moreover, Bolli's *Globigerina cretacea* occurs in Trinidad from the Cenomanian to the Santonian, whereas *G. cretacea* d'Orbigny was found in the upper Campanian (Craie blanche). It is evident that Bolli's species is not the same as d'Orbigny's species.

The author therefore will refer only to d'Orbigny's species in this publication. Study of Central American samples has shown that the species is much rarer in the

Cretaceous of that region. It may actually be restricted to the western and northern European area and North America, where it is abundant, at least in the upper Campanian. A close study of its origin and of its development after the upper Campanian reveals that d'Orbigny's species belongs to the gradual development series of a single biological unit, which will be referred to here as the *Globigerina cretacea* gens (in the sense of Vaughan, 1905).

D'Orbigny's *Globigerina cretacea*, as it occurs in the upper Campanian Craie blanche of Meudon, shows five or six chambers in the last-formed whorl and a strongly lobulate periphery. The spire is low-coiled, and one of the main features of the surface is the formation of distinct knoblike pustules between the fine pores which pierce the chamber walls on both sides and also at the margin (this is a distinct difference between our species and some globigerinid forms of *Marginotruncana* (*M. globigerinoides* Brotzen, *M. pura* Hofker), which always show a poreless margin. The species was also figured by Hiltermann and Koch (1955, pls. 28-29) from the upper Campanian and lower Maestrichtian of Lüneburg as *Globotruncana globigerinoides* Brotzen; restudy of their material has shown that the margins of those specimens have pores, so that they do not belong to that species but to the *Globigerina cretacea* gens.

In addition, d'Orbigny's species was described or figured by Schijfsma (1946, p. 93; good description, no figures) from the middle Campanian; by Hagn (1953, p. 92, pl. 8, fig. 5) from the lower upper Campanian;

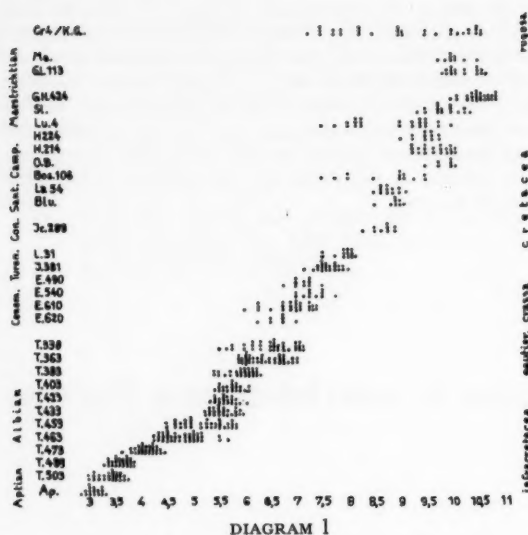


DIAGRAM 1

Diameters of the tests of the *Globigerina cretacea* gens in cm., when magnified \times ca. 70. During the development of the gens through different "species" a steady increase of the diameter is shown. All variants of each sample are plotted.

Hagn mentions that the species is found beginning in the Cenomanian and occurs also in the Albian as *G. infracretacea* Glaessner, which appears to be true; by Beissel (1891, pl. 13, figs. 43-47) from the lower Maestrichtian (the figures are very well drawn and accurate, corresponding fully to the types from the Craie blanche); by Franke (1928, p. 192, pl. 18, fig. 8); he states that the species is common in the entire Upper Cretaceous (his figure is accurate and his description good); and by Cushman (1931, p. 58, pl. 10, figs. 6-7) from the Selma chalk, which may be upper Campanian; Cushman's figures are very good and show all the typical features of the European specimens.

The gens *Globigerina cretacea* begins with *Globigerina infracretacea* Glaessner as first defined by Glaessner (1937, p. 28, text-fig. 1). It was reported as that species by ten Dam (1950, p. 54) from the Albian of the Netherlands, where it is very common, with a good description but no figure and with an exhaustive bibliography. Owing to the unfortunate definitions of the "genus" *Praeglobotruncana*, by Bermudez, 1952 and by Loeblich *et al.*, 1957, this species was put into this artificial genus, since in the Aptian-Albian specimens the aperture is interior marginal (Bolli, 1959, p. 266). However, this small species gradually changed into typical *Globigerina cretacea* d'Orbigny (not as described by Bolli). Bolli distinguishes these developmental stages as separate species, *Praeglobotruncana* sp. cf. *P. gautierensis* (Bronnimann) (Bolli, 1959, p. 266) and *Praeglobotruncana crassa* Bolli (1959, p. 265).

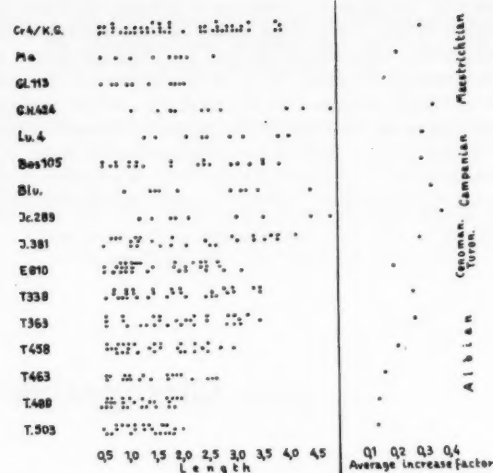


DIAGRAM 2

Increase of length of the chambers in tests of the *Globigerina cretacea* gens in cm., when magnified \times ca. 70. In each sample, one, two or three specimens were analyzed; the plots are to be read horizontally. It is shown that in the first developmental stages of the gens the average increase factor is in the vicinity of 0.1-0.2. Later, this factor increases to 0.3-0.4; and in the Maestrichtian, near the end of the gens, the rate of increase is slower.

When the typical stage of *Globigerina cretacea* d'Orbigny was reached in northwestern Europe, that species again developed gradually into forms which were combined by Bolli (1959) and by Bronnimann (1952) in *Rugoglobigerina rugosa* (Plummer). Plummer, however, described her species from the Navarro of Texas, 5 feet below the Midway, and thus from the uppermost Maestrichtian. In the uppermost Maestrichtian of northwestern Europe, nearly identical specimens are abundant, which show the "covering plate with extra openings" described by Plummer. In reality, these "plates" are not plates at all but are strongly developed tena which partly cover each other in the center of the ventral side, so perfectly that at low magnification they seem to form a single plate. Moreover, the borders of the plates must leave some openings for the protoplasm to stream out, hence the extra openings. Bolli, however, apparently also included the older forms, from the Santonian upward, in which the plates (tena) were not as well developed and did not cover each other, so that the extra openings were not necessary. Hence his designation of "*Rugoglobigerina rugosa* s.l.," ranging from the Turonian to the upper Maestrichtian. In addition, he also included in his "species" the true *Globigerina cretacea* d'Orbigny, but without mentioning that fact, since his "*G. cretacea*" (not the species of d'Orbigny) is a totally different species, ranging from the Cenomanian to the Coniacian.

GLOBIGERINA CRETACEA

There appear to exist different lines leading to forms with umbilical covering plates and a very rough surface, all of which are included in *Rugoglobigerina*. In northwestern Europe, such forms may have repeatedly penetrated from the Tethys region; we find them in the transition beds between the lower and upper Maestrichtian, but true *Rugoglobigerina rugosa* (Plummer), the end stage of the development of *Globigerina cretacea* d'Orbigny, occurs only in the upper part of the Maestrichtian, just as it does at its type locality, where it occurs in the Navarro immediately below the Midway.

Thus, analysis of the gradual developmental series of this single biological unit of planktonic foraminifera shows that it passed not only through several "species" (which thus must be regarded as artificial) but also through at least three different "genera" (*Praeglobotruncana* Bermudez, *Globigerina* d'Orbigny, and *Rugoglobigerina* Bronnimann), two of which must also be considered artificial.

The development of the biological unit (gens) *Globigerina cretacea* d'Orbigny appears to have been as follows:

In the Aptian of the Netherlands the species is very small and not common, but in a large series of samples taken every 5 meters through the Albian, it is very common. It changed gradually from a small form into a form of medium size, as shown in diagram 1. In the latest part of the Albian it acquired the features of *Praeglobotruncana* sp. cf. *P. gautierensis* (Bronnimann) as defined by Bolli (1959).

In the lower part of the Albian sequence studied, the species is small, with the characters of *Praeglobotruncana infracretacea* (Glaessner). In most forms the dorsal spire is low, and especially the last-formed chambers are very inflated toward the dorsal side. Moreover, in some specimens the last-formed chamber with its shining surface more or less covers the umbilical region in such a way that, in the nomenclature of Bolli, Loeblich and Tappan (1957), it would have been placed in the "genus" *Catapsydrax*. In the uppermost Albian the species is represented by a type no different from *Praeglobotruncana* sp. cf. *P. gautierensis* (Bronnimann).

In the Cenomanian the enlargement continued, as shown in diagram 1, with a form intermediate between *Praeglobotruncana crassa* Bolli and *Globigerina cretacea* d'Orbigny; the latter stage was reached in the Turonian. The increase in size continued during the Coniacian and Santonian, and stopped in the lower Campanian. From that time on, the largest diameter seems to have been reached.

In the meantime, the ornamentation of the test was also developing. The specimens from the Albian show fine tubercles on the surface. Those from the upper Albian and Cenomanian show more advanced ornamentation; here the tubercles are even larger. During the stage which is called *Globigerina cretacea* d'Orbigny, the tubercles became more and more distinct, so that in the lower Maestrichtian the surface became rough. In the

uppermost Maestrichtian of northwestern Europe, the surface is still extremely rough and aberrant forms begin to be found, some with five or even four chambers in the last-formed whorl, others that are much smaller than the preceding forms, and still others which show strong tena forming the "covering plate" with "extra openings" found in *Rugoglobigerina rugosa* (Plummer). The author has already shown that these covering plates were not completely fused together (Hofker, 1956, p. 372, text-fig. 6). Obviously, these forms indicate the approaching extinction of the gens (this phenomenon is also seen in the *Bolivinoidea decoratus-gigantus* gens, which ends with *Bolivinoidea polonicus* Pożaryska).

The apertural characters of the gens also changed gradually, together with the other changes. In the Albian forms we find the *Praeglobotruncana* type of aperture, which is an interumbilical-marginal aperture, at first a narrow slit with only a very narrow tenon covering it (more like a bordering lip). In that stage the umbilical cavity was also narrow. But the umbilical cavity became more and more enlarged and with it the aperture, which became distinctly crescent-shaped with a much more distinct tenon over it. In the uppermost Albian and Cenomanian, the aperture migrated continually farther into the larger umbilical cavity, and in the Turonian form it was more or less umbilical, with short tena over the umbilical cavity. During Coniacian and lower Maestrichtian time, the umbilical cavity continued to increase in diameter, and the size of the covering tena also increased; in the later Maestrichtian, they sometimes totally covered the large umbilical cavity. Finally, the large tena began to cover each other at the sides, and the extra openings found in *Rugoglobigerina rugosa* (Plummer) became necessary. Aberrant forms resembling *Globigerina esneensis* Nakkady and *Globigerina mckannai* White (*Globigerina supracretacea* Hofker), together with forms of the type of *R. rugosa* but with only four chambers in the last-formed whorl, are found in the transition beds between the upper Maestrichtian and Danian.

This analysis of the gens *Globigerina cretacea* can be summarized as follows:

- a) Aptian-Albian: *Praeglobotruncana infracretacea* (Glaessner) form;
Albian-Cenomanian: *Praeglobotruncana* sp. cf. *P. gautierensis* (Bronnimann) form;
Cenomanian-Turonian: *Praeglobotruncana crassa* Bolli form;
Turonian-upper Campanian: *Globigerina cretacea* d'Orbigny form with weak ornamentation;
Lower and middle Maestrichtian: *Globigerina cretacea* d'Orbigny form with strong ornamentation;
Upper Maestrichtian: *Rugoglobigerina rugosa* (Plummer) form, culminating in aberrant forms.
- b) The genera *Praeglobotruncana* and *Rugoglobigerina* are artificial and have no taxonomic significance.
- c) The gens *Globigerina cretacea* d'Orbigny is one more example of orthogenetic change in a biological

unit during the late Lower Cretaceous and Upper Cretaceous. Like so many other Cretaceous species, it suddenly ended its development with the end of the Cretaceous.

- d) Measurable characters of this gens (viz., test diameter) change rectilinearly with time.

In diagram 1, boundaries have been suggested between the different forms, but in reality these boundaries do not exist. In examining a series of samples, the observer is unaware of passages from one form into another. Although the range of variation was restricted at the beginning of the developmental series, it became wider at the end, at least with regard to test diameter. This phenomenon is known to occur in other orthogenetic series.

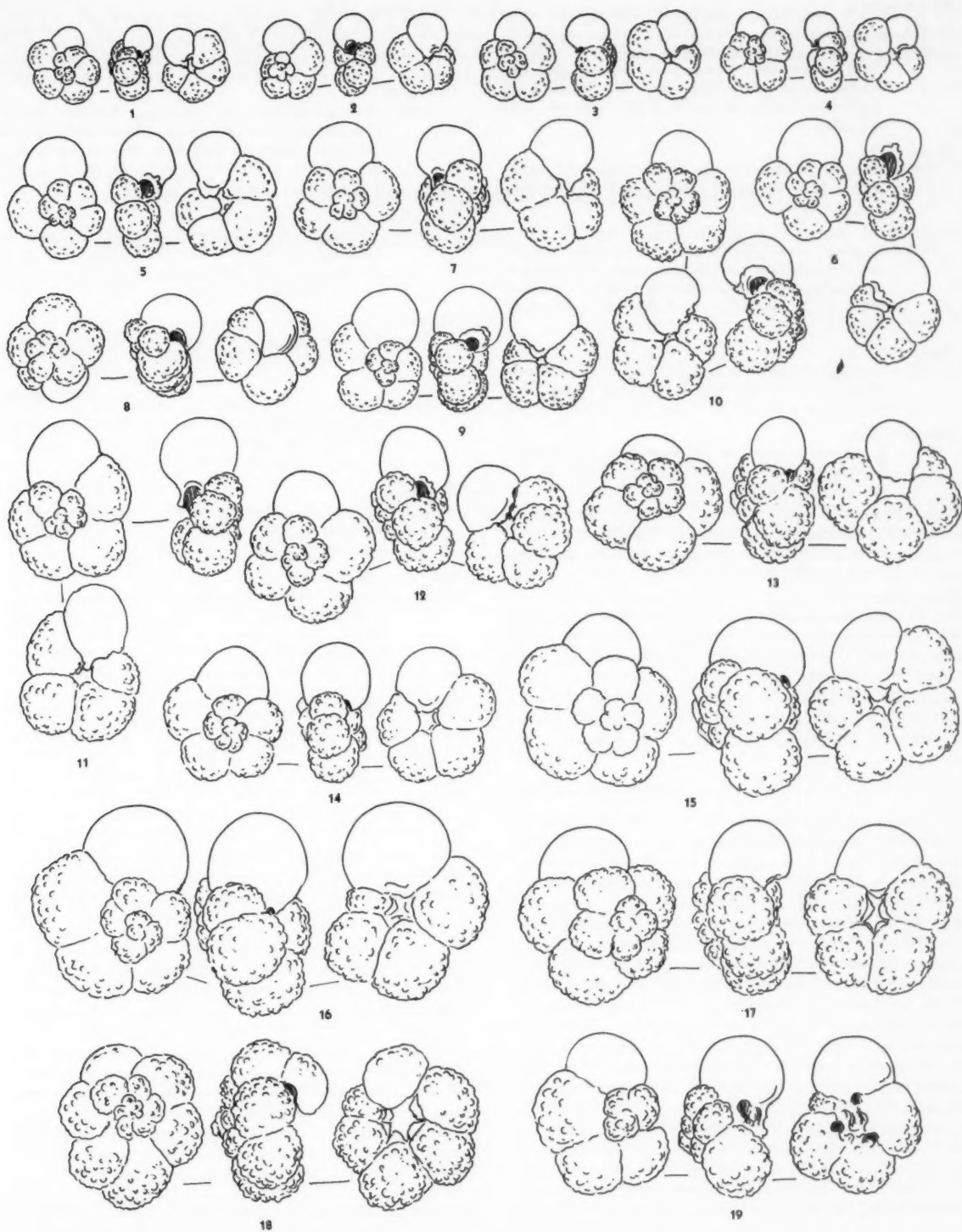
Young specimens were not included in the diagram. As will be seen from the figures, the number of chambers in the final whorl did not change during the long period in which the gens evolved, nor did the number of whorls, which is always three. Younger individuals always show about two whorls; full-grown specimens are much more common, with about three whorls in all.

The rapid increase in the volume of the chambers is also a constant character, as is the globular shape of the chambers. Nevertheless, the average increase factor of the last 8–11 chambers undeniably grew larger with time; this factor (the increase in the total width of the chambers divided by the number of chambers) began in the Albian at 0.13 and increased to 0.38 in the lower Maestrichtian; in the upper Maestrichtian it became somewhat smaller with the approaching extinction of the gens (this phenomenon was also found in the gens *Bolivinoidea decoratus*). The larger the tests, the faster the successive chambers increase in volume (diagram 2). This is all the more striking because the total number of chambers in the tests does not increase and because most of the tests measured begin with the same diameter in the first chamber measured (the eighth to eleventh chamber from the final one). We may therefore assume that the increase in the diameters of the entire tests is due to an increase in the factor by which the volumes of successive chambers in the last-formed whorl are increased. Perhaps the larger diameters of the chambers also caused the change in the apertural conditions, as a result of which the gens passed through the three so-called "genera" *Praeglobotruncana*, *Globigerina*, and *Rugoglobigerina*.

PLATE 1

Developmental stages of *Globigerina cretacea* d'Orbigny; all \times ca. 70.

- | | | | |
|------|---|----|---|
| 1–2 | <i>Praeglobotruncana infracretacea</i> (Glaessner) stage; lower Albian, Dutch well T. 503. | 12 | Form beginning to change into <i>Praeglobotruncana crassa</i> Bolli stage; upper Albian, Dutch well T. 363. |
| 3–4 | Same form but somewhat larger; lower Albian, Dutch well T. 488. | 13 | <i>Praeglobotruncana crassa</i> Bolli stage; Albian–Cenomanian boundary, Dutch well T. 363. |
| 5–6 | Intermediate form between <i>Praeglobotruncana infracretacea</i> (Glaessner) and <i>Praeglobotruncana</i> sp. cf. <i>P. gautierensis</i> (Bronnimann) of Bolli; middle Albian, Dutch well T. 463. | 14 | <i>Praeglobotruncana crassa</i> Bolli stage; Cenomanian, 610 meters in a well at Emlichheim, Germany. |
| 7 | Nearly the same stage but slightly younger; the typical form of <i>Praeglobotruncana</i> sp. cf. <i>P. gautierensis</i> (Bronnimann) of Bolli; Albian, Dutch well T. 458. | 15 | <i>Globigerina cretacea</i> stage; Turonian, 5381 meters in a well at Itterbeck, Germany. |
| 8 | Another form from the same sample as figure 7, with the large end-chamber covering the umbilical cavity and thus resembling <i>Catapsydrax</i> (T. 458). | 16 | <i>Globigerina cretacea</i> stage; Coniacian, 289 meters in a shaft at Ickern, Germany. |
| 9–10 | A still more advanced form of the <i>Praeglobotruncana</i> sp. cf. <i>P. gautierensis</i> (Bronnimann) stage; upper Albian, Dutch well T. 383. | 17 | <i>Globigerina cretacea</i> stage; Campanian–Maestrichtian boundary, sample 4 from Lüneburg, Germany. |
| 11 | Same form, somewhat later in geologic time (T. 373). | 18 | <i>Globigerina esneensis</i> Nakkady form, one of the aberrant stages from the uppermost Maestrichtian; <i>Pseudotextularia</i> zone, Maasbühl well no. 1, Germany. |
| | | 19 | Typical <i>Rugoglobigerina rugosa</i> (Plummer) stage; uppermost Maestrichtian, Hofker sample 628, top of Cr 4, Canal Albert, Belgium. |



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ABSTRACT *Relative abundance of miospore types is a powerful criterion for stratigraphic identification of coal beds. Precision of this technique is improved by application of simple statistical tests, such as Chi-square, which allow objective evaluation of the data. To be conducive to statistical analysis, quantitative collection and treatment of samples is essential. In order to characterize spore populations with adequate precision, many spores must be counted and grouped into few types.*

Elementary statistics applied to palynologic identification of coal beds*

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INTRODUCTION

In Indiana, all coal beds of Pennsylvanian age contain abundant miospores, spores smaller than 0.2 mm. in diameter. Effective use of miospores for stratigraphic identification of the coal beds involves both statistical and taxonomic factors. Only statistical aspects will be discussed in this report.

Miospores are commonly used as index or guide fossils, but because they are abundant they are well suited to statistical techniques designed to compare entire assemblages of spores. In order to identify stratigraphically an exposure of a coal bed by means of its miospore assemblage, it is necessary to sample the bed, isolate the spores contained in the sample, classify the spores into recognizable categories, and compare the relative abundance of the various spore types with their abundance in a known sample. If it is assumed that each coal bed contains a distinct miospore assemblage that does not differ from place to place, the problem then consists essentially of evaluating sampling error in the statistical sense.

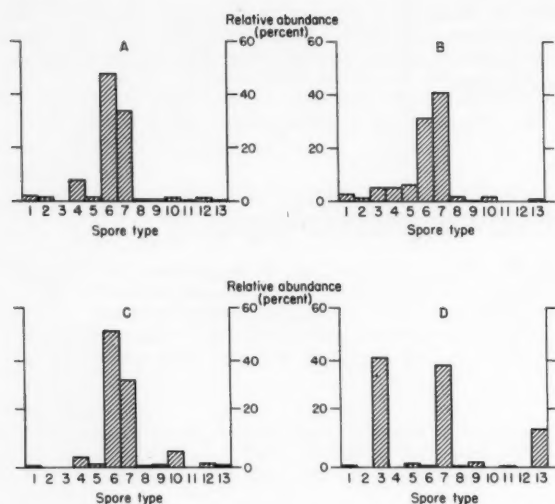
Sample counts in themselves are exact, but comparable parameters of the parent population may only be estimated. The range of values within which the true proportion of a spore type can be expected to lie with a given probability is called the confidence interval. Spore-population data are binomially distributed, because whatever specimen is chosen from a given sample, each is or is not of a particular type and each has exactly the same chance of being found to be of that particular type. Such data conform to a special case of the binomial expansion, from which the name is derived. In Table 1 are listed some representative values of the

confidence interval for binomially distributed data; complete tables or charts are given in textbooks on statistics (Snedecor, 1946, p. 4-5; Walker and Lev, 1953, p. 461). If, for example, 10 percent of a total count of 250 spores belongs to genus *A*, then there is 95 percent probability that the true abundance of this genus is between 7 and 14 percent. The proportions of only the more abundant spore types may be estimated with much precision, and these only by counting a rather large number of spores. The degree of this uncertainty determines to a large extent the precision that may be expected of techniques designed to compare samples.

SAMPLING FOR STATISTICAL STUDIES

Samples of coal from which spore assemblage data are to be gathered must be collected in a strictly quantitative manner. It is common practice to take separate samples for each conspicuous layer, or bench, in a coal bed. This procedure is unsatisfactory for statistical studies because spores are present in each bench in unequal abundance; some thick benches are nearly barren and some thin benches are rich in spores. Unless information is available on the extent of the contributions from each bench it is impossible to reconstitute data from bench samples for comparison with data from samples taken from the whole bed or from places where the development of benches is different. Whole-bed samples are therefore preferred. If benched samples are desired, a whole-bed sample should also be taken, or else the benched samples should be of size proportionate to bench thickness so that an estimate may be made of the total abundance of spores in each bench. The relative abundances may then be adjusted to reflect fairly the contribution of each bench to the spore population of the whole coal bed.

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TEXT-FIGURE 1

Graphic presentation of miospore population estimates; 200 spores counted in each sample.

COMPARISON OF MIOPORE ASSEMBLAGE DATA

Graphic summaries of spore population data showing the relative abundance of each spore type may be compared visually (text-fig. 1). The limitations of this method are obvious; it is only as objective and free of bias as he who judges the comparisons. If sample A is taken as the control, most readers will agree that sample C compares well and sample D does not, but there will be disagreement on the comparison of sample B with the control.

A simple statistical test that can be used to minimize the subjective elements involved in comparing these samples is the Chi-square test (Table 2). The value of Chi-square is computed according to the following formula:

$$\chi^2 = \sum \frac{(f-F)^2}{F}$$

To obtain the values of the expected frequencies (F), the observed frequencies (f) for each spore type are summed and proportioned back according to the total counts in each sample. Thus the expected frequency of spore type 1 in sample A (Table 2) is $(4 + 6) \times \frac{200}{400} = 5$.

(It is not necessary that the sample sums be equal; hence in other cases expected frequencies are not simple arithmetic mean values.) Chi-square represents the summation of the squares of the differences between observed and expected frequencies divided by the expected frequencies, for all spore types in both samples. It is therefore a measure of the difference between the abundance of the various spore types in the sample counts being compared and the abundance of these spore types in hypothetical parent populations, the

TABLE 1

95 PERCENT CONFIDENCE INTERVALS FOR BINOMIAL DISTRIBUTION

Proportion observed in sample	Total number of spores counted		
	100	250	1,000
1%	<5%	<4%	<2%
2%	<7%	1-5%	1-3%
5%	2-11%	3-9%	4-7%
10%	5-18%	7-14%	8-12%
20%	13-29%	15-26%	18-23%
40%	30-50%	34-46%	37-43%

parameters of which are represented by the values listed as expected frequencies. If the sample counts differ greatly from the hypothesized parent population values, Chi-square will be large; if the difference is slight, Chi-square will be small.

It is now necessary to know whether the value of Chi-square computed in Table 2 is sufficiently large to indicate that samples A and B probably could not have been taken from identical parent populations. This may be learned by comparing the computed value, 33.2, with values listed in a standard table of Chi-square (Walker and Lev, 1953, p. 464; Croxton, 1959, p. 328-329). To do this, the number of degrees of freedom in the computation of Table 2 must be known. The number of degrees of freedom is the maximum number of figures that can be chosen freely and inserted into the Chi-square computation; given these figures and the sums of each row and each column, all other figures are then automatically defined. In the general case, the number of degrees of freedom equals the number of rows minus one, times the number of columns minus one; thus for the example in Table 2 there are 12 degrees of freedom.

Opposite 12 degrees of freedom in the standard table are several values of Chi-square, each of which is associated with a certain probability, p (Table 3). If samples are actually drawn from identical populations, the given values of Chi-square will be exceeded only with probability p . Thus the probability of samples A and B representing identical populations is vanishingly small; or, stated otherwise, the value of Chi-square computed for these two samples is beyond any reasonable limit of acceptability.

In setting arbitrary limits of acceptability it is necessary to recognize a statistical dilemma. These limits may be manipulated somewhat so as not to reject too many comparisons between samples that actually represent identical parent populations, or so as not to accept too many comparisons between samples that actually represent different parent populations. The first risk is the

STATISTICS APPLIED TO PALYNOLOGY

TABLE 2

SPECIMEN COMPUTATION OF CHI-SQUARE

Sample	Frequency	Spore type													Sum observed
		1	2	3	4	5	6	7	8	9	10	11	12	13	
A	observed f	4	3	0	16	3	96	68	1	1	3	1	3	1	200
	expected F	5.0	3.0	5.5	13.5	8.0	79.5	75.0	2.5	1.0	3.5	0.5	1.5	1.5	—
B	observed f	6	3	11	11	13	63	82	4	1	4	0	0	2	200
	expected F	5.0	3.0	5.5	13.5	8.0	79.5	75.0	2.5	1.0	3.5	0.5	1.5	1.5	—
Sum observed		10	6	11	27	16	159	150	5	2	7	1	3	3	400

$$\chi^2 = \frac{1^2}{5} + \frac{0^2}{3} + \frac{5.5^2}{5.5} + \frac{2.5^2}{13.5} + \frac{5^2}{8} + \frac{16.5^2}{79.5} + \frac{7^2}{75} + \frac{1.5^2}{2.5} + \frac{0^2}{1} + \frac{0.5^2}{3.5} + \frac{0.5^2}{0.5} + \frac{1.5^2}{1.5} + \frac{0.5^2}{1.5} + \frac{1^2}{5} + \frac{0^2}{3} + \frac{5.5^2}{5.5} + \frac{2.5^2}{13.5} + \frac{5^2}{8} + \frac{16.5^2}{79.5} + \frac{7^2}{75} + \frac{1.5^2}{2.5} + \frac{0^2}{1} + \frac{0.5^2}{3.5} + \frac{0.5^2}{0.5} + \frac{1.5^2}{1.5} + \frac{0.5^2}{1.5} = 33.2$$

TABLE 3

SELECTED VALUES OF CHI-SQUARE FOR 12 DEGREES OF FREEDOM

p	χ^2
10%	18.5
5%	21.0
2.5%	23.3
1%	26.2
0.5%	28.3

TABLE 4

SUMMARIZED COMPUTATION OF LINEAR CORRELATION COEFFICIENT
(calculated across 108 samples of 200 spores each)

	Genus X (<i>Laevigatosporites</i>)		Genus Y (<i>Latosporites</i>)
ΣX	7,090	ΣY	864
ΣX^2	686,056	ΣY^2	15,044
		ΣXY	84,140
		r	.647

TABLE 5

SELECTED VALUES OF THE CORRELATION COEFFICIENT
 $N = 108$

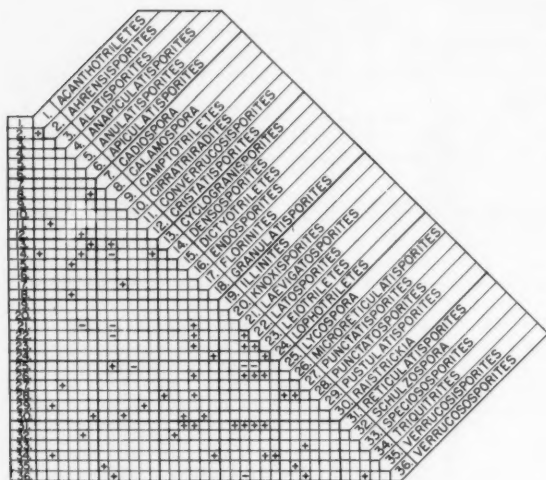
p	r
5%	.159
2.5%	.189
1%	.223
0.5%	.247
0.05%	.312

"acceptance level" and is the same as p in Table 3. The 5 percent level indicates that only 5 percent of valid comparisons will be rejected, a result of the normal sample variation previously discussed. The second risk ordinarily cannot be evaluated because the actual parameters of the parent populations are commonly unknown. An increase in the acceptance level will be accompanied by an increase of unknown proportions in the second type of risk. The acceptance levels that are most commonly used, mainly because they intuitively seem most reasonable, are 5 percent and 1 percent. At either of these levels, the hypothesis that samples A and B represent identical parent populations must be rejected.

The Chi-square value calculated for the comparison of samples A and C (text-fig. 1) is 15.0, and that for the

comparison of samples A and D is 231.2. At the 5 percent level sample A compares acceptably only with sample C; this statement is essentially objective, and anyone following the same routine would arrive at the same conclusion. The corollary statement that these two samples came from the same coal bed depends upon the validity of the original assumptions and may or may not be true. Compatible assemblages are sometimes found in samples that are widely spaced stratigraphically. Additional information is required to evaluate ecologic or other factors that may have caused such repetitions of spore assemblages.

Chi-square is a simple test but it is somewhat tedious; routine application of this test is most readily performed with the aid of high-speed digital electronic data-

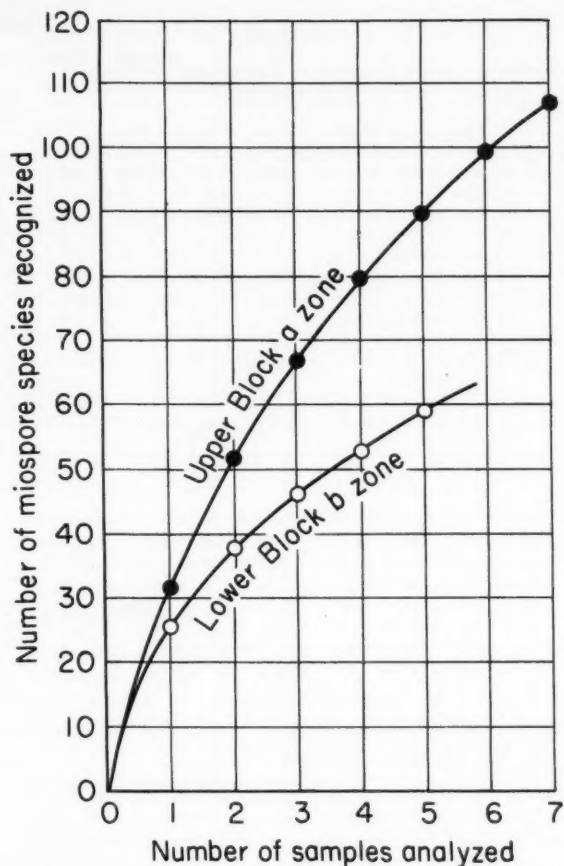


TEXT-FIGURE 2

Positive and negative correlations at the 99 percent significance level between all possible pairs of miospore genera, across 108 samples from coal beds of Pennsylvanian age in Indiana.

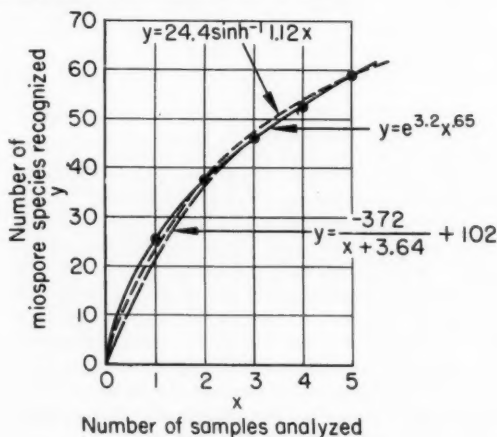
processing machinery. Computations such as that in Table 2 are carried out in a second or two by machine; hand calculation, with checking, takes 20 minutes or more.

A major objective of most spore population studies is to group samples that have like populations. The tolerance allowed in accepting members into a group will affect not only the estimate of the group mean values but also the allowable deviation from the mean. The Chi-square test can be applied to any group as a test of homogeneity, but because a very large number of possible groups may be formed from only a moderate number of samples, some shortcuts must be found. One permissible shortcut is to arrange the samples so that no sample will be compared with any sample or group that is so far above or below it stratigraphically that the comparison would be of no value in stratigraphic identification. A second shortcut is to build groups slowly, comparing step by step, rather than to form groups at random for testing. Thus, to an already-tested homogeneous group of any size, one sample is added; the value of Chi-square for the new group is calculated and compared with the limit of acceptance. If the new group proves to be homogeneous, another sample is added; if not, the sample most different from the group mean is discarded before the addition of the next sample. This is not a rigorous application of Chi-square, and there are some undesirable aspects, such as the effects of the order in which new samples are added, but the technique is simple and does permit the formation of homogeneous groups of samples. For routine application of this procedure electronic computers are almost essential.



TEXT-FIGURE 3

Relation of number of species recognized to number of samples in two coal beds in Indiana.



TEXT-FIGURE 4

Mathematical approximations to the species/sample curve for the Lower Block b Zone.

STATISTICS APPLIED TO PALYNOLOGY

TABLE 6

MIOSPORE GENERA COMBINED FOR STATISTICAL PURPOSES

(Mean abundance approximated from 108 samples from coal beds of Pennsylvanian age in Indiana.)

36 genera (according to Potonie and Kremp, 1954)	Mean abundance (percent)	12 genera plus "wastebasket" (modification of Schopf, Wilson and Bentall, 1944)	Mean abundance (percent)
<i>Calamospora</i>	3.7	<i>Calamospora</i>	3.7
<i>Cirratriradites</i>	2.9	<i>Cirratriradites</i>	2.9
<i>Anulatisporites</i>	1.6		
<i>Densosporites</i>	1.9	<i>Densosporites</i>	3.5
<i>Endosporites</i>	9.9	<i>Endosporites</i>	9.9
<i>Granulatisporites</i>	1.7		
<i>Lophotriletes</i>	0.4	<i>Granulatisporites</i>	2.1
<i>Laevigatosporites</i>	29.7		
<i>Latosporites</i>	3.6	<i>Laevigatosporites</i>	33.3
<i>Lycospora</i>	26.5	<i>Lycospora</i>	26.5
<i>Microreticulatisporites</i>	1.9		
<i>Verrucosporites</i>	0.1	<i>Microreticulatisporites</i>	2.0
<i>Punctatisporites</i>	3.8	<i>Punctatisporites</i>	3.8
<i>Punctatosporites</i>	4.0	<i>Punctatosporites</i>	4.0
<i>Dictyotriletes</i>	0.1		
<i>Knoxisporites</i>	0.1		
<i>Reticulatisporites</i>	0.8	<i>Reticulatisporites</i>	1.0
<i>Ahrensiporites</i>	0.6		
<i>Triquitrites</i>	0.6	<i>Triquitrites</i>	1.2
<i>Acanthotriletes</i> , <i>Alatisporites</i> , <i>Anapiculatisporites</i> , <i>Apiculatisporites</i> , <i>Cadiospora</i> , <i>Camptotriletes</i> , <i>Converrucosporites</i> , <i>Cristatisporites</i> , <i>Cyclogranisporites</i> , <i>Florinites</i> , <i>Illinites</i> , <i>Leiotriletes</i> , <i>Pustulatisporites</i> , <i>Raistrickia</i> , <i>Schulzospora</i> , <i>Speciososporites</i> , <i>Verrucosporites</i>	6.1	All others	6.1

STATISTICAL ASPECTS OF CLASSIFICATION SCHEMES

In order to make the most effective use of Chi-square, some limitation must be placed on the number of spore types used. It has been shown (Table 1) that the proportions of only the more abundant types are determined with much precision. Miospores recognized in coals of Pennsylvanian age in Indiana are presently classified into 36 genera according to the taxonomy of Potonie and Kremp (1954). Few of these genera are abundant enough to characterize a population properly, and the resultant uncertainty is expressed as a needlessly high number of rejections among the Chi-square comparisons.

Pairs of genera that could be combined without detriment to their use in the Chi-square test may be signaled by a statistic known as the correlation coefficient (r),

which is computed according to the following formula (Walker and Lev, 1953, p. 234):

$$r = \frac{N\sum XY - (\sum Y \sum X)}{\sqrt{[N\sum X^2 - (\sum X)^2] [N\sum Y^2 - (\sum Y)^2]}}$$

The counts of the two genera being compared in N samples are represented by X and Y . An example of the computation of the correlation coefficient is summarized in Table 4. Entire data are not given, as they would be too voluminous; each sum shown is composed of the individual counts in 108 samples.

The calculated value of r may be compared with standard tables, such as that shown in abbreviated form in Table 5. Complete tables are found in statistics textbooks (Snedecor, 1946, p. 149; Walker and Lev, 1953, p. 470). The correlation coefficient ranges from -1

through zero to +1. Values nearer to 1, whether positive or negative, indicate a stronger correlation. Positive correlations indicate direct relationships of the sort $X = aY$; where one type is more abundant, the other is also. Negative correlations indicate inverse relationships of the sort $X = \frac{a}{Y}$; where type X is more abundant,

type Y is rarer. The values of r listed in Table 5 will be exceeded only with probability p , given the number of cases, or samples, involved in the comparisons, if there is in fact no correlation between X and Y . Thus it is probable that *Laevigatosporites* and *Latosporites* (Table 4) are positively correlated; there is considerably less than 0.05 percent probability (Table 5) that the figures in Table 4 could represent genera that are actually not correlated. The correlation coefficient between *Laevigatosporites* and *Densosporites* is -0.1315 ; this is too small to indicate a correlation. *Laevigatosporites* and *Calamospora* are negatively correlated ($r = -0.3895$); again, there is less than 0.05 percent probability that these genera are not negatively (inversely) correlated.

Correlation coefficients calculated for all possible pairs of genera across a large number of samples are summarized in text-figure 2. Positive correlations may be the result of similar stratigraphic distribution, similar ecologic preference, or similar botanical affinity. It is desirable to retain a botanical significance to the spore-type groupings used, so only those correlated genera that show strong morphologic similarity should be combined (Table 6).

The number of spore types recognized in the coal beds of Indiana is thus reduced from 36 to 12, plus a waste-basket category for genera whose frequencies are inadequate for precise estimation of their abundance. For use in the Chi-square test it would be advisable to eliminate all classes of less than 5 percent abundance, but there seem to be valid botanical and stratigraphic reasons for retaining for analysis all the genera listed in the right-hand column of Table 6.

In general, calculation of Chi-square with a smaller number of spore types produces more meaningful results. Computational noise contributed as a result of relatively insignificant fluctuations in the infrequent types is minimized. The presence or absence of a specimen of an infrequent type is more a function of the laws of chance than of geologic or botanical factors. Such types are therefore unreliable stratigraphic indicators.

Some pairs of genera show a strong negative correlation, one being consistently more abundant where its counterpart is less so (text-fig. 2). The inverse correlation of *Laevigatosporites* and *Lycospora* is a result of their being the two most abundant genera; where one is more abundant, the other must consequently be less so. Other negative correlations are probably a function of ecologic or stratigraphic factors. To isolate and evaluate these factors it is necessary to make use of some more elaborate statistical procedure, such as analysis of variance.

STATISTICAL ASPECTS OF SPECIES LISTS

The species list of miospores identified with a particular coal bed is clearly a function of the number of samples (or spores) catalogued from that bed. Each of the curves shown in text-figure 3 was constructed from species lists representing all those samples that appear, from both spore-assemblage and stratigraphic evidence, to belong to the zones named (Guennel, 1958). Each point on each curve represents the average of all possible combinations of the given number of samples among the total number used. For instance, 5 samples representing the Lower Block b Zone are available; the third point on the curve representing this zone is an average of the number of species recognized in all 10 possible combinations of the 5 samples taken 3 at a time. This procedure smooths the curve, but also places perhaps undue importance on points near the ends of the curve.

Excellent approximations to these curves are obtained from exponential curves close to a parabola in shape (text-fig. 4, solid line). But parabolas never level off, never become asymptotic to a finite number of species. Appropriate curve types that have asymptotes include hyperbolas (text-fig. 4, long-dashed line) or hyperbolic sine curves (text-fig. 4, short-dashed line), both of which are asymptotic to the maximum expectable number of species, in this case approximately 100. Neither of these curves appears to fit the data as well as the simple exponential curve, however, and the question remains: is it possible that the species list of a single coal bed is really infinite in length?

Thanks are due to Dale J. Hall, Chief Programmer, Indiana University Research Computing Center, for assistance with the electronic computations, and to Robert F. Blakely, Geophysics Section, Indiana Geological Survey, for assistance in fitting the curves of text-figure 4.

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A mechanized method of breaking down and washing foraminiferal rock samples

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INTRODUCTION

The method and apparatus herein described has been developed during several years of experimenting with a variety of techniques. Although speed of sample processing has been one object of mechanization, a balance of the three following factors has been maintained: quality of the finished residue, quantity of the sample processed, and reduction of contamination to a minimum. The dimensions of the apparatus given in this paper are those most suitable for handling a sample of up to approximately 36 cubic inches. By reducing these dimensions a greater number of smaller samples can be handled. The apparatus is set up in pairs, which permits quicker sample processing.

The writer wishes to thank Mr. N. de B. Hornibrook, Senior Micropaleontologist, New Zealand Geological Survey, for his helpful advice and suggestions.

METHOD OF PROCESSING

The samples are first soaked in water and detergent, in numbered jars, the number being noted on each sample record form which accompanies the sample throughout processing.

After having been soaked for approximately 24 hours, six samples are boiled in six one-pint enamel pots on a gas heated iron plate (text-fig. 1a). Tightly fitting lids prevent splashing from one pot to another.

Harder samples are crushed in a manually operated crusher (text-fig. 2a). A simple rack and pinion mechanism (text-fig. 2b) above the crushing head is operated by a 3 foot lever, and adequately crushes even the hardest samples. The head has a detachable sheet iron cover fitted for easy cleaning (text-fig. 2c), and a rectangular tray (text-fig. 2d) is used to hold the sample, which is crushed in a little water.

When sufficient sample has been crushed, and the portion that passes through an 8-mesh sieve is transferred to a rubbing cylinder (text-fig. 3a), it is then fixed in position on the mixer for rubbing (text-figs. 2e and 3b). Rubbing time varies according to the hardness and quantity of the sample, but the process may be aided by pouring the sample into the washer and washing away surplus mud, before continuing rubbing (see under heading "washing apparatus to replace fine (200) mesh sieves"). Experience shows that most moderately soft samples need only 5 to 10 minutes rubbing, but certain types of sticky mudstones and cemented rocks take longer. Only enough water should be added to form a thin sludge, but as the sample is broken down more water is usually required to prevent caking around the walls of the cylinder.

When rubbing is complete, the sample is finally washed in the cylindrical washer described below and transferred to a tray for drying (text-fig. 1b). During the drying period, contamination can result from splattering caused by overheating. An oven designed to overcome this problem is shown in text-figure 1c. Each tray is placed in a separate, closely fitting, easily cleaned cover of thin sheet metal (text-fig. 1d), before drying off. A current of air is drawn over the samples from an overhead duct by an extractor fan to facilitate drying (text-fig. 1e).

Various sizes of pillboxes are used for storing the dry residues. Diameters from one inch to two and a half inches are the most satisfactory. Relevant details of each sample are written on the lids for easy reference.

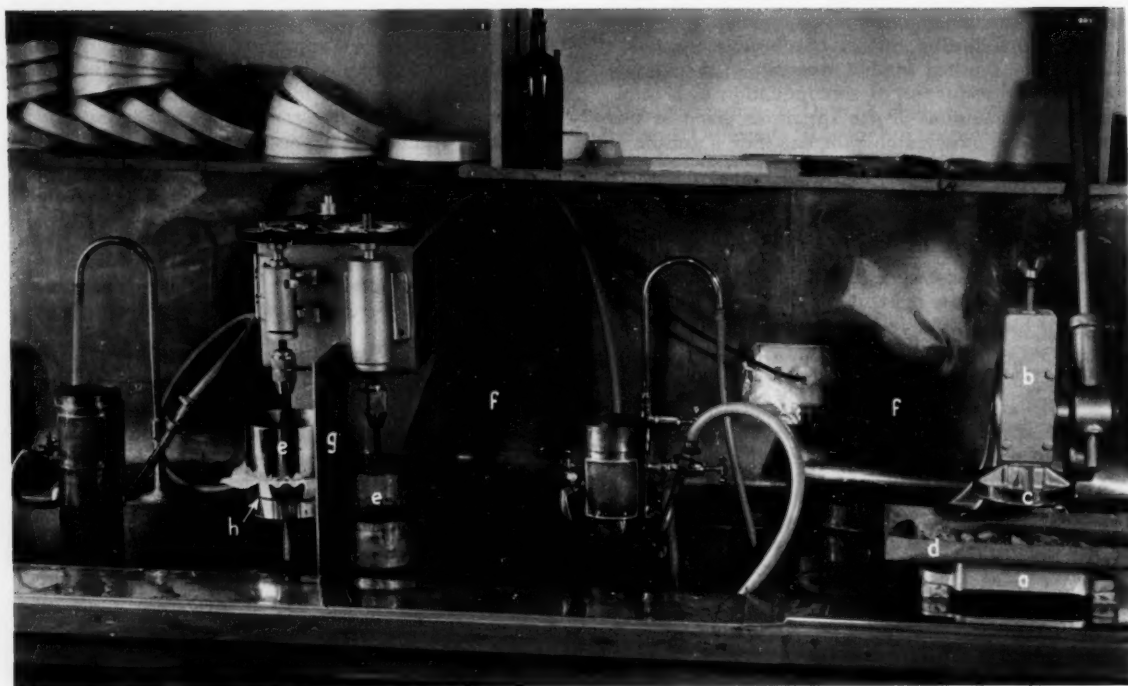
Finally, the number of each sample is entered in a register, in the order of washing, as a means of checking possible contamination by previous samples.



TEXT-FIGURE 1

BOILING AND DRYING UNIT

a, Hot plates; b, drying tray; c, drying oven; d, splatter covers; e, air duct to extractor fans.

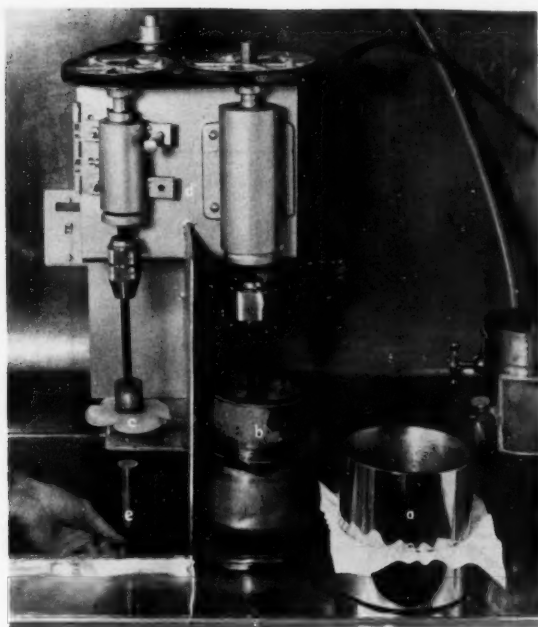


TEXT-FIGURE 2

CRUSHING, RUBBING AND WASHING UNITS

a, Crusher; b, rack and pinion mechanism; c, cover on crushing head; d, tray containing sample; e, mixing cylinders; f, brass sheeting; g, mixer; h, spring wire band.

MECHANIZED WASHING METHOD



TEXT-FIGURE 3
RUBBING UNIT

a, Mixing cylinder; b, mixing cylinder in position for rubbing; c, rubbing head; d, mixer; e, adjustable stand.

CLEANING OF EQUIPMENT

Both mixer and washers are operated in a trough 5 feet long, 13 inches wide and 7 inches deep, which arrangement permits sludge to wash away while processing takes place. Sheet brass covers the bench tops, and is carried 2 feet up the wall behind, (text-figs. 2f and 5), to permit the hosing down of all apparatus after each sample is processed. A separate sink nearby is used for washing small items of equipment, thereby minimizing the risk of contamination.

MECHANICAL RUBBING APPARATUS

Mechanical rubbing or agitation of foraminiferal samples, although detrimental if too prolonged, is often necessary to separate specimens cleanly from the matrix before washing.

The main advantages of the process described below are, the wider range of hard rocks that can be washed, and the large size of the samples that can be processed reasonably quickly. Furthermore, the apparatus may be left running without attention for short periods of time.

This apparatus duplicates, as nearly as possible, the comparatively gentle rubbing action of "silking" described by W. H. V. Baker in "The Micropaleontologist," vol. 5, no. 4, pp. 37-40, 1951. Although it is



TEXT FIGURE 4

RUBBING HEAD AND CYLINDER COMPONENTS

a, Plastic rubbing head; b, stirring rod; c, fixing flange; d, brass cap; e, cylinder components with rubber sheet.

simple to operate and clean, it requires some degree of skill and judgement on the part of the operator. It minimizes greatly the drudgery of processing quantities of difficult samples by the more standard methods. Furthermore, the time of the laboratory technician is much more economically spent as he is free to attend to other samples while the apparatus is running.

A spinning rubber disc (text-fig. 3c) is gradually brought into contact with a sheet rubber diaphragm held pinched between the two, closely fitting halves of a chromium plated steel rubbing cylinder (text-figs. 3a and b). The rubbing action is sufficiently gentle not to damage the majority of specimens, but is usually sufficient to separate the finest particles. An adjustable stand permits the pressure put on the rubbing surfaces to be varied. Two grades of rubber sheeting have proved sufficient to cope with any type of sample suitable for washing.

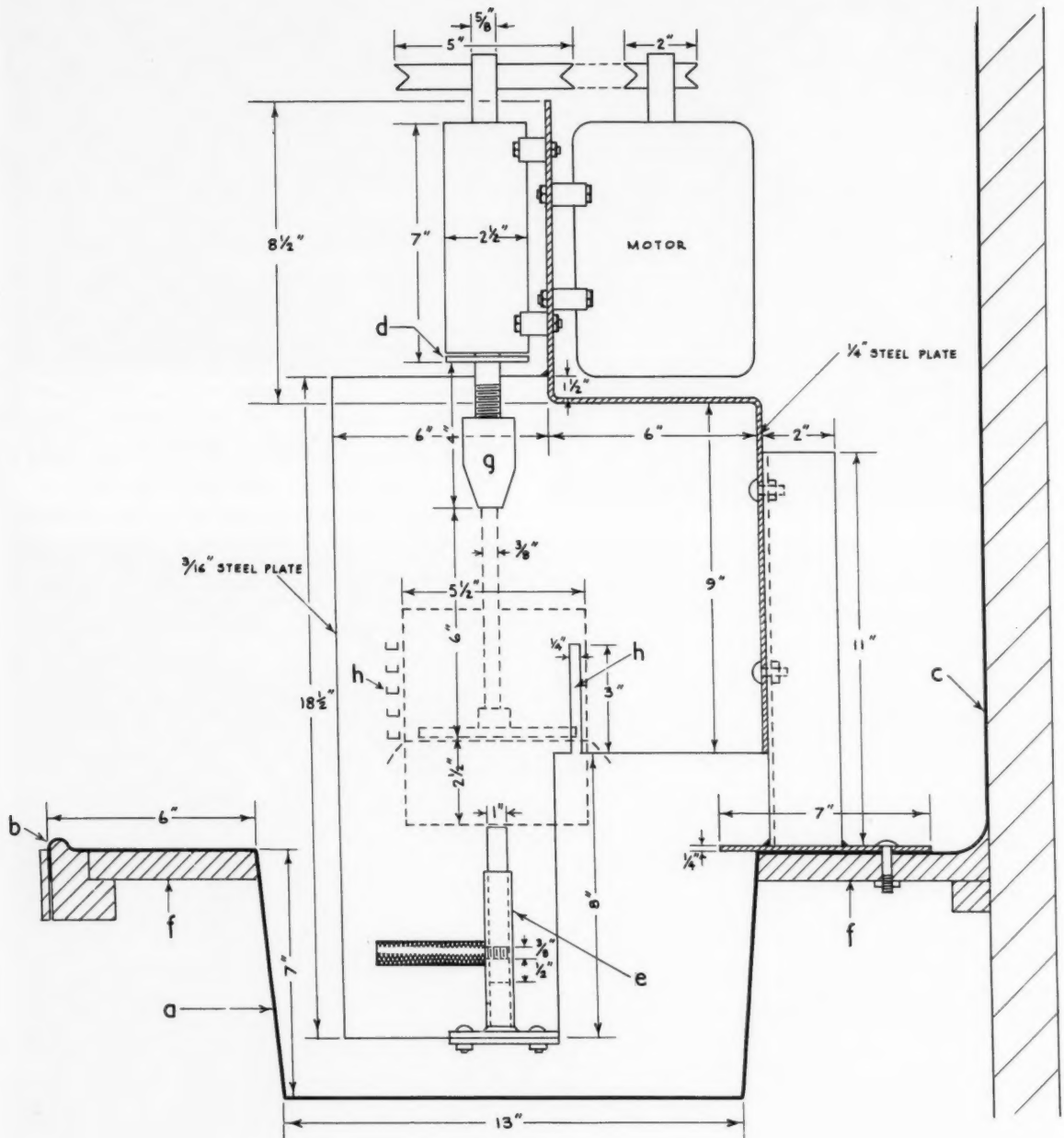
CONSTRUCTION

Three main parts comprise the bulk of the apparatus:

a) An electrically driven mixer, powered by a $\frac{1}{4}$ h.p., 1450 r.p.m. motor connected by a belt and pulleys, b) plastic agitating heads on steel stirring rods, c) steel cylinders for holding rubber diaphragms.

a) The mixer (text-fig. 3d) is chiefly constructed of steel, with brass adjustable stands (text-figs. 3e and 7). All steel work is heavily coated with aluminum paint which has proved an effective protection against rust. The dimensions shown in cross section (text-fig. 5) are those of a heavy duty, all purpose mixer, capable of rubbing two samples at once (text-fig. 2g). As the motor is shielded from water, the front of the mixer can be thoroughly hosed down after each sample is completed.

b) Two types of agitating heads are necessary, an average weight for moderately soft samples, and heavy duty for hard samples. The average weight head is used with a thin rubber diaphragm, and the heavy duty with a thick diaphragm. Because the diaphragms wear,

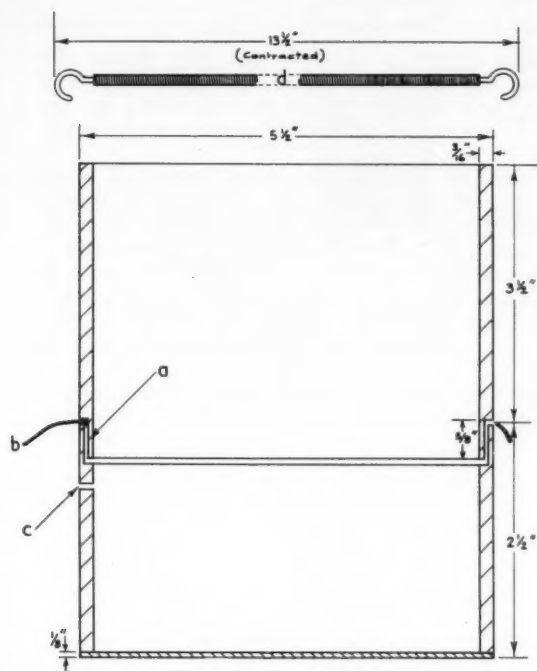


TEXT-FIGURE 5

SCHEMATIC DIAGRAM OF RUBBING UNIT

a, Brass trough; b, turned-up flange on bench; c, brass sheet extended up wall; d, protective collar below bearing; e, adjustable stand (brass); f, bench top; g, chuck ($\frac{3}{8}$ "); h, loops and groove to accommodate spring holding-bands.

MECHANIZED WASHING METHOD



TEXT-FIGURE 6

CONSTRUCTION OF MIXING CYLINDER

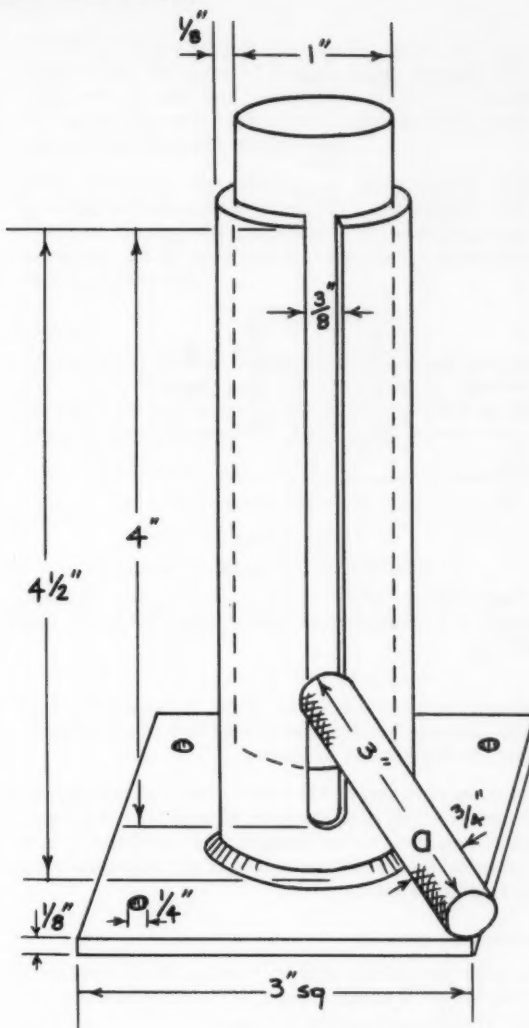
a, Space necessary to accommodate rubber sheet;
b, rubber sheet; c, hole allowing escape of air as cylinders
are pushed together.

and eventually break, the lower portion of the mixing cylinder is closed and acts as a basin to catch the sample when breakage occurs.

Dimensions for each head are shown in text-figure 8, as is the method of fixing the steel rod into the plastic so that the heads can be easily removed and cleaned. The plastic used to cast the heads is polyvinyl chloride, which is very tough, but flexible.

c) The rubbing cylinders are also of simple construction. Text-figure 4e shows a cylinder taken apart, text-figure 3a shows it reassembled ready for use, and text-figure 2e shows agitators and cylinders in position under the mixer. The surfaces of the cylinder are chromium plated inside as well as out. The dimensions are given in text-figure 6. The gap between the press-in sleeves (text-fig. 6a) is determined by the thickness of the rubber sheeting used. The two halves of the cylinders should fit together tightly enough to prevent springing apart when in use. For soft samples, rubber sheeting .013 inches thick has been found most suitable and 0.061 inches for hard samples.

A coiled spring wire band (text-figs. 2h and 6d) clips tightly round the cylinder, holding it in place while rubbing proceeds.



TEXT-FIGURE 7

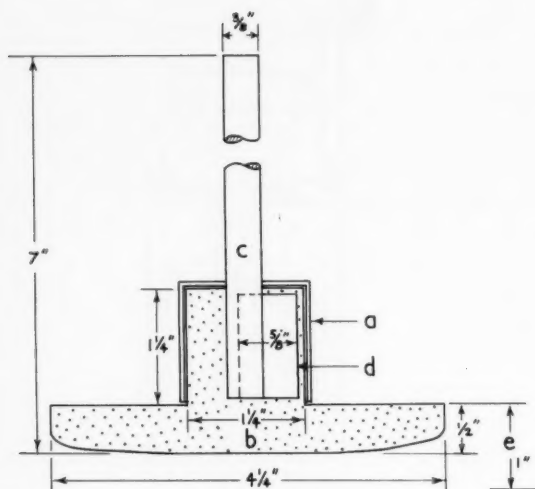
CONSTRUCTION OF ADJUSTABLE STAND

a, Locking handle.

WASHING APPARATUS TO REPLACE FINE MESH SIEVES

When fine sticky muds are washed over a 200 mesh sieve, as they are in many laboratories, they are often very troublesome because they clog the fine screen. Mechanical agitation of the sediments on the gauze only damages the latter and breaks up delicate specimens. The present method has been devised to eliminate clogging and to reduce the destruction of foraminiferal tests.

The principle upon which this washer works is quite simple, and experience has shown it to be an improvement over the usual method of working sediment



TEXT-FIGURE 8

CONSTRUCTION OF RUBBING HEAD

a, Brass cap; b, plastic head; c, stirring rod; d, fixing flange; e, increased thickness of head for heavy duty rubbing.

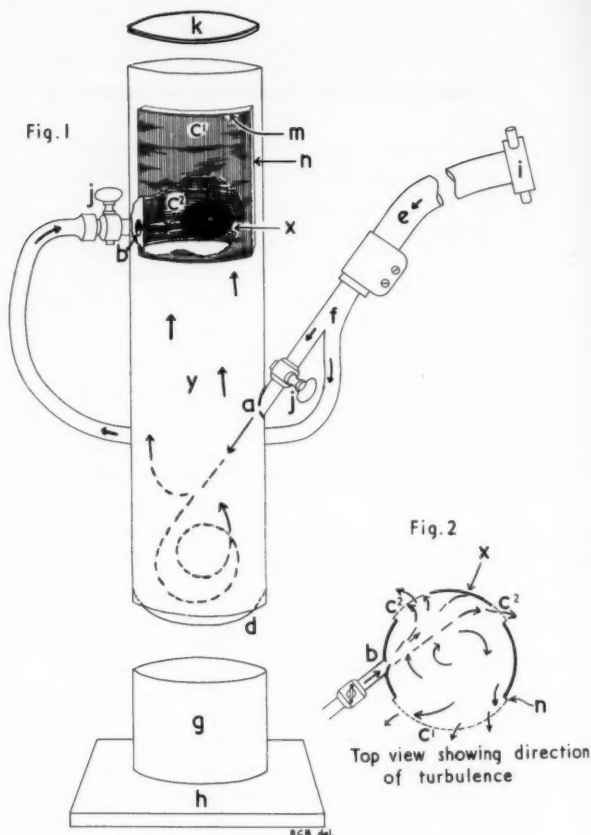
through standard fine mesh sieves. A reasonably high water pressure (approximately 100 lbs per square inch), is needed for efficient operation.

The main advantage of the apparatus is that it rapidly removes the bulk of the sample. Ease of handling, small area of wire mesh to be cleaned, and the elimination of mechanical or manual treatment of the microfossils are also important assets.

Construction and maintenance

The main part of the washer (text-figs. 9-10) consists of a cylinder of 16 gauge copper, 4" in diameter and 14" long (y) with a hemispherical bottom (d). Two opposing 200-mesh phosphorous-bronze gauze windows, $3\frac{1}{2}$ " square, are located 2" below the top of the cylinder (c, 1 and 2), and two separately controlled, high pressure water jets are set in the sides as shown in text-figure 9 (a, b). Small gas taps are quite suitable for water jets (j). For the water connections to the jets, half-inch copper pipe is used (f), joined to the water tap by plastic hose (e).

Continuous washing of various types of samples has shown that the main cause of wear on the gauze is the friction of sand grains held in suspension as they pass through the mesh. Higher water pressure means a shorter life for the gauze, which normally lasts from 3-4 months, depending on the quantity and type of samples being washed. Sandy samples wear through the gauze quickest. A small metal disc soldered on the spot where the stream from the jet (b) makes contact with the gauze helps to cut wear considerably (x) and does not affect the efficiency of the washer.



TEXT-FIGURES 9-10

SCHEMATIC DIAGRAM OF WASHER

a, Jet directed downwards to stir mud into suspension; b, jet directed at gauze window; c, (1 and 2) 200-mesh gauze windows; d, hemispherical bottom; e, plastic hose to main water tap; f, $\frac{1}{2}$ " copper pipe; g, collar for washer to sit in; h, lead base; i, main hose connection; j, gas taps used for water jets; k, clear plastic lid to stop splash; m, gauze soldered on edge of flange; n, turned-out flange $\frac{3}{8}$ " wide; x, metal disc soldered on gauze where jet (b) causes most wear; y, copper cylinder (16-gauge).

The gauze is replaced by cutting it out with a knife and soldering in a new piece. To facilitate quick replacement, a narrow copper flange $\frac{3}{8}$ " wide is turned outwards around the edge of the window (n), and the gauze soldered to its edge (m) as shown in window (c).

A heavy base to keep the washer upright consists of a lead slab 6" square and $\frac{1}{2}$ " thick (h) with a collar 4" high and $4\frac{1}{8}$ " inside diameter (g). The bottom of the washer sits in this base, text-figure 9.

MECHANIZED WASHING METHOD

Operation

The sample must first be broken down by soaking, boiling, rubbing or chemical treatment, and passed through a 10 or 20 mesh sieve to eliminate large lumps. The resultant sludge is poured into the washer.

Jet (a) is directed downwards to mix the sediment and bring it into suspension. As the water level rises, jet (b), which is directed at one of the gauze windows, is turned on to keep the gauze clear and carry away the fine mud. Careful control of both jets is essential. If jet (b) is not kept wide open the gauze windows tend to become blocked with sediment (text-fig. 10, top view showing general direction of turbulence).

Average samples, which have been broken down reasonably well beforehand, usually require no more than

10-15 minutes washing. Any combination of pressures required by the type of sample being washed can be obtained on the jets. Bentonitic clays, for example, which become very sticky when soaked in water, usually take longer than soft sandstones.

After washing, the residue is removed by simply pouring off the surplus water in the cylinder, and by carefully tipping the remainder into a drying tray. If necessary, jet (a) may be turned on at the same time to facilitate removal.

Cleaning

Cleaning the washer is easy, provided seams and joints are cleanly finished. A large toothbrush is effective in cleaning the gauze, and when jet (a) is turned on full it removes any sediment left in the bottom.

Annotated bibliography of micropaleontology in Poland

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This bibliography is restricted to papers that are concerned with micropaleontology and microstratigraphy or which mention microscopic fossils. In addition to foraminifera, this bibliography covers spores and pollen, ostracodes, and other animal microfossils.

ADAMCZAK, F.

- 1959 - *Sur certaines modifications pendant l'ontogenèse des ostracodes dévoniens*. Acta Pal. Polonica, vol. 4, no. 2, pp. 195-206.

A study of the ontogeny of nine ostracode species from the Middle Devonian of the Holy Cross Mountains.

ALEXANDROWICZ, S.

- 1959 - *Les sédiments du Crétacé supérieur à Nowa Cerekwia près de Głubczyce*. Soc. Géol. Pologne, Ann., vol. 29, no. 2, pp. 165-179.

The author gives the microfaunal characteristics of Upper Cretaceous sediments from Nowa Cerekwia, determining their age as Coniacian, or probably upper Turonian.

- 1959 - *Age of transgressive Miocene deposits at Mazatowice near Bielsko (western Carpathians)*. Kwart. Geol. I. G., vol. 3, pp. 662-676.

In addition to Miocene foraminifera, reworked Cretaceous and Eocene forms also appear in the basal conglomerate of Miocene age. The foraminiferal assemblage is characterized by an abundance of calcareous benthonic and planktonic species.

ALEXANDROWICZ, Z.

- 1959 - *Carboniferous foraminifera from Kozłowa Góra near Bytom (Upper Silesia)*. Kwart. Geol. I. G., vol. 3, pp. 869-881.

In the Upper Carboniferous sediments of the Upper Silesian basin, foraminifera appear rarely and are concentrated in marine intercalations. The presence of numerous foraminifera is established in Kozłowa Góra. Accordingly, with the aid of palynological analysis, the sediments can be considered as a marine horizon of the Hrusov beds (Namurian A).

BIEDA, F.

- 1959 - *Nummulites of the Magura series*. I. G. "Z badań geologicznych w Karpatach," Biul. 131, pp. 5-37.

An investigation of the nummulite fauna of the Magura series of the Polish western Carpathians. Four different stratigraphic zones have been distinguished.

- 1959 - *Fauna velkých Foraminifer od Velké Čausy*. Geol. Ústav D. Stura, vol. 53, pp. 97-104.

The author describes several species of Carpathian Slovakian larger foraminifera, chiefly nummulites. He states that there is a great resemblance with the nummulite assemblage of the French Alps described by J. Boussac.

BIELECKA, W. and PAZDRO, O.

- 1959 - *O problemie pozornej niezgodności stratygraficznej między mikrofauna a makrofauna*. (Polish.) Przegląd Geol., no. 10, pp. 450-553.

Specific cases of similarity among stratigraphically different foraminiferal assemblages is discussed. This is believed to be caused by similar facies conditions. Moreover, examples of partial and total derivation of some assemblages are given.

BŁASZYK, J.

- 1959 - *Two new upper Bathonian ostracods of the genus Progonocythere*. Acta Pal. Polonica, vol. 4, no. 4, pp. 431-447.

Two new species of ostracodes are described from the *Clydoniceras discus* zone in Poland. The ontogeny and development of the hinge in the successive instars of one species have been studied.

- 1959 – *Foraminifera of the middle Bononian from Brzostówka near Tomaszów Mazowiecki (central Poland)*. Kwart. Geol. I. G., vol. 3, pp. 713–720.

The paper discusses problems of micro-paleontologic stratigraphy of the middle Bononian of central Poland. The identification of foraminiferal assemblages enabled the author to confirm the appearance of the *Provirgatites scythicus* and *P. alexandrae* zones.

DABROWSKI, M. J.

- 1959 – *Late-glacial and Holocene history of Białowieża Primeforest*. Acta Soc. Bot. Pol., vol. 28, no. 2, pp. 197–248.

The paper presents the history of the Białowieża National Park forests using pollen analysis. The forest shows characteristic development from Alleröd to Holocene, indicating a very close connection with north-western regions. At the same time, these forests are clearly distinct from those of eastern Europe. Other special features of Białowieża are an early appearance of spruce and also a relatively early development of hornbeam.

DOKTOROWICZ-HREBNICKA, J.

- 1959 – *Some pollen grains of Taxodiaceae Family in the Tertiary brown coal*. Kwart. Geol. I. G., vol. 3, pt. 1, pp. 721–736, pt. 2, pp. 1033–1050.

The author identifies certain Tertiary fossil pollen grains with papillae which correspond to species and genera of the Taxodiaceae. The author hopes to use these forms for their index value for further stratigraphic investigations. On the basis of the structure of Recent pollen grains of *Sequoia*, *Cryptomeria*, *Taxodium* and *Metasequoia*, the author demonstrates that there exists a group of particular morphological features for each species and genus. The Polish Tertiary brown coal types, hitherto investigated palynologically, may be grouped from youngest to oldest age, according to clearly defined pollen and spore assemblages.

DYAKOWSKA, J.

- 1958 – *On the possibility of determining the pollen of some species of the genus Abies*. Acta Biol. Cracoviensia, vol. 1, pp. 57–68.

In studies dealing with the Polish Pleistocene, the possibility of pollen determination of two fir species, namely of *Abies alba* and *Abies Fraseri*, is very important; because the appearance of the latter was determined in the Masovien Interglacial (Mindel-Riss) of Poland. With the help of three criteria, it was possible to determine, palynologically, the species of fir in fossil state. These criteria are: 1) a high percentage of pollen grains with the ratio of the breadth of the body to the depth of the sac (A/B) equal to 1 or less than 1;

2) the characteristic distribution of the ratio A/B; and 3) the relatively small size of the pollen grains. One locality of Holocene age and one from the Eemian Interglacial (Mindel-Riss) were investigated. In all these profiles, the culmination of the curve of *Abies* was the object of the examination.

- 1959 – *Podrecznik palynologii (Textbook of Palynology)*. (Polish.) Wydawnictwa Geologiczne, 325 pp., 6 pls.

The textbook consists of the following twelve chapters:

- 1) The history of palynological research.
 - 2) The morphology of pollen grains and spores.
 - 3) Production of pollen and spores and their dispersal.
 - 4) Palynology and medicine.
 - 5) Palynology in apiculture.
 - 6) Palynology in the systematics of plants.
 - 7) Pollen analysis.
 - 8) Pollen analysis in the study of the Holocene.
 - 9) Pollen analysis in the study of the Pleistocene.
 - 10) Palynological problems in the investigations of older sediments.
 - 11) Palynological analysis in the study of the Tertiary.
 - 12) Palynology in the study of pre-Tertiary rocks, especially Carboniferous.
- Appendix. – Equipment indispensable for the operation of a palynological laboratory.

DYAKOWSKA, J. and ZURZYCKI, J.

- 1959 – *Gravimetric studies on pollen*. Acad. Pol. Sci., Cl. II, Bull., vol. 7, no. 1, pp. 11–16.

The authors present the results of weight measurements of pollen grains of twenty-six species. Their average dimensions and, for some species, the speed of falling in motionless air, are compared. The data obtained made it possible to state that, though the weight of a pollen grain is generally proportional to its size, a list of species arranged in order of diminishing weights is similar to a list of diminishing sizes. There are, however, quite considerable deviations.

DUSZYŃSKA, S.

- 1959 – *Devonian foraminifera from Wydrzysów (Holy Cross Mountains)*. Acta Pal. Polonica, vol. 4, no. 1, pp. 71–89.

The author describes seven Couvinian species of foraminifera, four of which are considered new.

GEROCH, S.

- 1959 – *Stratigraphic significance of arenaceous foraminifera in the Carpathian Flysch*. Pal. Zeitschr., vol. 33, no. 1/2, pp. 113–122.

MICROPALEONTOLOGY IN POLAND

Some groups of arenaceous foraminiferal assemblages have been distinguished in the Polish Carpathian Flysch. This has made possible stratigraphic correlation of a series containing no calcareous microfauna, and situated in various tectonic units or in different regions of the Carpathian Flysch. The sequence and characteristics of these groups are presented for the continuous Silesian series in the western Carpathian Flysch.

GÓRKA, H.

1957 - *Coccolithophoridés du Maestrichtien supérieur de Pologne*. Acta Pal. Polonica, vol. 2, no. 2-3, pp. 235-284.

The author describes skeletal elements of Coccolithophoridae from the upper Maestrichtian of Kazimierz and Góra Puławska on the Vistula border (central Poland). Among sixty-six species described, sixty are new. Two new genera, *Dictyolithus* and *Nephrolithus* are also described.

JACHOWICZ, A.

1959 - *Spore associations and stratigraphic position of coal seams at Kozłowa Góra (Upper Silesian Basin)*. Kwart. Geol. I. G., vol. 3, pp. 883-897.

A coal outcrop, whose stratigraphic position has not yet been accurately determined, furnished well-preserved material consisting of megaspores, microspores, pollen and fully preserved microsporangia. It appears, from a stratigraphic analysis of the most important species of spores, that the coal exposed at Kozłowa Góra should be assigned to the Hrusov beds (Lower Namurian A).

JURKIEWICZ, H.

1959 - *Otwornice z warstw Magurskich i Podmagurskich w rejonie Pielgrzymki*. (Polish.) Przegląd Geol., no. 5, pp. 202-204.

A list of foraminiferal assemblages from the Magura and Submagura series, with corresponding stratigraphic conclusions, is given.

1959 - *Microfaunal correlation in the Paleogene of the eastern part of the Silesian nappe*. Soc. Géol. Pologne, Ann., vol. 29, no. 3, pp. 235-363.

The local stratigraphic subdivision of Paleogene beds from the eastern part of the Silesian unit is given on the basis of the microfaunal assemblages.

JURKIEWICZ, H. and KARNKOWSKI, P.

1959 - *Age of Inoceramus beds in the Magura nappe*. Acta Geol. Polonica, vol. 9, no. 1, pp. 17-50.

Data obtained from a microfaunal study in three successive horizons of *Inoceramus* beds are given: 1) the sandstone horizon, 2) the sandstone-slate horizon, and 3) the slate horizon together with the lower part of the variegated Paleogene.

KARNKOWSKI, P.

1959 - *Jankowa Anticline (middle Carpathians)*. Soc. Géol. Pologne, Ann., vol. 29, no. 3, pp. 281-296.

The Jankowa Anticline consists of Upper Cretaceous and Paleogene beds belonging to the Silesian flysch series. The stratigraphic division of this series and the distribution of microfaunal assemblages are presented.

KOZŁOWSKI, R.

1959 - *Un microfossile énigmatique*. Acta Pal. Polonica, vol. 4, no. 3, pp. 273-277.

Under the name of *Clistrocystis graptolothophilus* n. gen., n. sp., the author describes a very interesting chitinous Ordovician microfossil whose shape resembles a padlock.

KSIĄŻKIEWICZ, M. and LISZKOWA, J.

1959 - *Subsilesian series near Golezów (Silesia)*. Kwart. Geol. I. G., vol. 3, pp. 91-102.

In the small tectonic windows near Golezów, Middle-, Upper Cretaceous and Eocene beds are present, mainly as marly or argillaceous deposits. The determination of the age of these beds is based on their foraminiferal assemblages. The stratigraphic units have also been determined.

KUHL, J.

1959 - *Microspores in coal ashes*. (Polish.) Rev. Géol. (Przegląd Geol.), no. 10, pp. 467-468.

Ashes, remaining after the burning of Carboniferous humus-coal in a temperature of about 400°C., contain some very well-preserved spores.

LISZKOWA, J.

1959 - *Microfauna from beds with exotics at Bachowice*. I. G. "Z badań geologicznych w Karpatach," Biul. 131, pp. 39-110.

The beds at Bachowice, containing exotics, have microfaunal assemblages with a stratigraphic range from upper Campanian to lower Eocene. The foraminifera with agglutinated tests usually occur in shales and those with calcareous tests in clays.

MACKO, S.

1959 - *Pollen grains and spores from Miocene brown coals in Lower Silesia-I*. Soc. Sci. Lettres Wrocław, Trav., ser. B, no. 96, pp. 1-108, pl. 1-67.

The author describes pollen and spores from three localities in Lower Silesia. The detailed pollen analysis of brown coal shows that the repeated appearance of almost all fossil pollen and spores have the diagnostic features of Recent pollen and spores. The names of the fossil types are defined. From the author's experience, it can be said that comparative analysis, in order to be fruitful, must be carried out by the detailed comparison of fossil and Recent pollen and spores.

MORGIEL, J.

- 1959 - *The microfauna of the Babica clays*. I. G. "Z badań geologicznych w Karpatach," Biul. 131, pp. 111-147.

Two assemblages occur within the investigated microfauna; agglutinating and calcareous-agglutinating ones. It has become customary to assign the Babica clays to the Paleocene, but the calcareous-agglutinating assemblage indicates an Upper Cretaceous age.

NOWAK, W.

- 1959 - *Geology of the Carpathian border between Andrychów and the Soła River*. I. G. "Z badań geologicznych w Karpatach," Biul. 131, pp. 149-202.

The paper discusses the geology of the Carpathian border, where the author has distinguished the Silesian and the Subsilesian series, the so-called Opole and the Grabowiec substages, and the zone formed by the alternating flysch and Miocene shales. All series are differentiated on the basis of their microfauna.

PACHUCKI, C.

- 1959 - *Über die Stratigraphie und Lithologie der Kreide im Neissegraben*. Univ. M. Curie-Skłodowska, S. B., Ann., vol. 12, no. 1, pp. 1-65.

The lithologic aspect and the paleogeography of Upper Cretaceous deposits in the Nysa Kłodzka region are described. The stratigraphic sequence is presented and the mega- and microfaunal assemblages are given.

PAZDROWA, O.

- 1959 - *On the stratigraphic distribution of Miliolidae in the Middle Jurassic of Poland*. Acta Geol. Polonica, vol. 9, no. 3, pp. 343-381.

A report is made on the stratigraphic distribution and reciprocal quantitative relations of Miliolidae studied in a number of Middle Jurassic profiles, chiefly in the vicinity of Częstochowa, Rawa Mazowiecka and Łęczycza. The presence of these forms in other regions of Poland is confirmed. Their facies and stratigraphic significance is discussed. Two new species of the genus *Miliolina* are described.

POŻARYSKI, W. and POŻARYSKA, K.

- 1959 - *Comparaison entre le Crétacé de la Belgique et de la Pologne*. Soc. Géol. Belgique, Ann., vol. 82, pp. 1-14.

The paper is an attempt to give a general comparison between Belgian and Polish Upper Cretaceous strata on the basis of mega- and microfossils.

ŚLĄCZKA, A.

- 1959 - *Stratigraphy of the Bystre scale (middle Carpathians)*. I. G. "Z badań geologicznych w Karpatach," Biul. 131, pp. 203-268.

The stratigraphic sequence of the Cretaceous and Paleogene of the Silesian unit occurring in the middle Carpathians is discussed. The foraminiferal assemblages in each of the series are presented.

ŚRODOŃ, A.

- 1959 - *Żarys historycznego rozwoju szaty roślinnej Polski w późnym glacyale i postglacyale*. (Polish.) Wyd. "Szata Roślinna Polski," T. I., vol. 7, pp. 513-543.

Late glacial and Holocene floras are characterized on the basis of pollen analysis. The author describes the succession of floral development, beginning with preglacial tundra assemblages of the Baltic glaciation up to their Recent differentiation.

STACHURSKA, A.

- 1959 - *The morphology of pollen grains of Pterocarya hupehensis* Skan. Acta Soc. Bot. Pol., vol. 28, no. 2, pp. 315-317.

The author describes the morphology of pollen grains of *Pterocarya hupehensis* Skan. from the collection of the Herbarium of the Royal Botanic Garden in Edinburgh. The author notes some new, different features in the pollen grains of *P. hupehensis* Skan. which have diagnostic value in micropaleobotanical investigations.

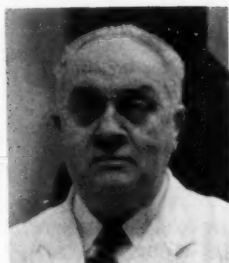
WOLAŃSKA, H.

- 1959 - *Agathammina pusilla* (Geinitz) from the lower Zechstein in the Sudeten and Holy Cross Mountains. Acta Pal. Polonica, vol. 4, no. 1, pp. 27-50.

Detailed study of about six hundred individuals of *Agathammina pusilla* were made. The composition and structure of the shell wall, morphology of the test and micro- and megalospheric forms are described. The systematic position of this species is determined.

news reports

FRANCE



JEAN CUVILLIER

INSTITUT FRANÇAIS DU PÉTROLE (I.F.P.)

As part of the paleontological research for various contracts, conodonts and foraminifera of Paleozoic formations have been intensively studied by Mr. Lys and Mrs. B. Serre in various basins in France, Belgium, and the western Sahara.

A colloquium on the Paleozoic stratigraphy of the Sahara in September, 1959, enabled the specialists of different companies to discuss various problems concerning the Carboniferous period and its micropaleontological aspects. These meetings, organized jointly by the Bureau de Recherches de Pétrole (B.R.P.) and the Institut Français du Pétrole (I.F.P.), which have in the past considered certain Cambro-Ordovician problems, met in May, 1960, in order to discuss the Gotlandian-Devonian. We regret the departure of Mrs. B. Serre, who has been replaced by Miss A. Mauvier.

Post-Paleozoic foraminifera, for the most part collected by research teams in Spain, have been studied by both Mr. Sigal and Mr. Lys. Mr. Lys has presented a study of the Cretaceous-Tertiary boundary by means of

pelagic foraminifera from the Majunga Basin, Madagascar, at the International Geological Congress in Copenhagen. J. Sigal is completing a joint paper with J. Espitalie on the foraminifera in the Malm-Neocomian formations. He is also continuing studies of the Vocontian (Cretaceous) of the Alpine Priabonian sections, and of the Malm in the Jura region. Miss A. Guillo-teau has resumed work, under his direction, on the calcareous algae which was begun in 1950 by Miss Coquillat. Mrs. Bizon has participated in foraminiferal studies of the Lias of the Paris Basin.

A systematic catalogue of Paleozoic Ostracoda has been established; it follows along the same lines as the recent works of Henningsmoen (Oslo) and Pokorny (Prague). V. Apostolescu has published an article on the Lias Ostracoda of the Paris Basin (1959, *Rev. Inst. Franc. Pétr.*), and he will present a paper at the Lias Colloquium held in 1960 at Chambéry (Savoie). N. Grekoff has written a second volume on the Cretaceous Ostracoda of the Belgian Congo and prepared an article on fossil fresh-water ostracodes for the International Geological Congress in Copenhagen. He has also taken part in a study of Mesozoic Ostracoda collected in Spain. G. Deroo is now on a mission in Teheran.

Among the persons who have studied foraminifera, ostracodes, or conodonts in the Laboratory were: Mr. S. Abdusselamoglu (Technical University, Istanbul), Miss Bazoché (SNREPAL, Algiers), Miss Borragan (ADARO, Madrid), Miss Fernet (C.F.P., Bordeaux), Miss Fradet (S.A.P.C.O., Bordeaux), Mr. Conil (University of Louvain), Mr. Guha (Oil and Natural Gas Commission, Dehra Dun, India) and a few Iranian students (N.I.O.C.). We

also were visited in September, 1959, by Prof. V. Pokorny, who collected samples from some type areas and who discussed several problems of the Carpathian flysch series.

The team of palynologists, directed by B. de Jekhowsky, included a number of specialists, technicians, assistants and students at the beginning of 1960. The laboratory devotes a large amount of time to the teaching and the perfecting of specialists interested in palynology. The stratigraphic subjects which have been investigated include the Silurian-Devonian-Carboniferous chitinozoa, hystrichosphaerids and spores of the Sahara, as well as the Permian, Triassic, and Jurassic spores of Madagascar. Among the articles dealing with problems studied in 1958, which have now been published, were: Correlation in the Tertiary of the Paris Basin (B. de Jekhowsky and C. P. Varma, 1959, *Rev. Inst. Franc. Pétr.*); and a review of the Mesozoic microfloral associations in the Aquitanian region of France (J. Taugourdeau-Lantz and B. de Jekhowsky, 1959, *C. R. Somm., Soc. Géol. France*).

UNIVERSITÉ DE PARIS

Since June, 1959, the Department of Micropaleontology has been occupying a new building with more room for the staff and the students. The regular staff now includes Prof. J. Cuvillier, head of the Department, Mrs. M. Neumann, Miss A. Rouvillois and Mrs. Taugourdeau. Lectures in sedimentology are delivered by M. Boulanger; several specialists who are not members of the Department have taken part in the teaching. All branches of micropaleontology are included in the instruction, which comprises six lectures per week and ten hours of laboratory exercises.

The students of the first year, about thirty, are being prepared for the "Certificat de Micropaléontologie." In the second year, the same number of students deal with research work, partly field work and partly study of the material collected, as well as microfacies and macrofaunas. Palynology now has an important part in this research work.

More than twenty theses in micropaleontology are in progress; a dozen students of both first and second years had been employed by the end of 1959, by several oil companies, both in France and outside the country. It would take too long to give the titles of all the subjects under study; they generally are studies of the stratigraphy of different regions, more or less in connection with petroleum exploration. In addition to these very specialized works in preparation, eight theses are under way for the Doctor of Science degree, as well as five or six "Diplômes d'études," corresponding to the first steps in research, for students who are not quite prepared for advanced research. Several geologists from France and elsewhere spent three to six weeks each to improve their knowledge of micropaleontology.

The "Revue de Micropaléontologie," of which volumes 1 and 2 have been published, is well under way. Its organization and distribution account for a large part of the activities of the staff, with the help of Mrs. Le Blanc acting as Secretary for the Revue.

ECOLE PRATIQUE DES HAUTES-ETUDES,
PARIS

The final transfer of the Laboratory to the new building of the Paleontology Department of the Museum was effected in May 1959, and the reorganization of the service has followed swiftly.

On the occasion of the Colloquium on the French Upper Cretaceous held at Dijon (Congrès des Sociétés Savantes), Professor G. Deflandre presented a paper entitled "Paléoplanctologie du Crétacé supérieur français" (published in "Comptes

rendus du Congrès, 1959, p. 57-60) giving the present state of our knowledge of the calcareous microorganisms (especially coccolithophorids), the siliceous microorganisms (radiolaria, diatoms, chrysomonads and silicoflagellates), and the non-mineralized microorganisms, dinoflagellates, hystrichospheres and others. In a paper, "Sur les nanofossiles calcaires et leur systématique" (Rev. Micropal., 1959), after giving a short historical review and a stratigraphic sketch, some general and specific critical notes tend to induce an improvement of the present system of classification. A number of new families (*Lithostromationidae*, *Nannoconidae*, *Schizophaerellidae*), new genera (*Kamptnerius*, *Zygrhablithus*, *Marthasterites*, *Micro-rhabdulus*, *Lucianorhabdus*) and new species are defined or proposed. In another field, which can be of interest for the Quaternary research workers, Professor G. Deflandre has written chapter 9, Rhizopoda and Actinopoda, for the second edition of the long out-of-print Ward and Whipple's "Freshwater Biology" (New York, John Wiley and Sons Inc., 1959). Another paper in press in Revue de Micropaleontologie entitled "A propos du développement des recherches sur les Radiolaires fossiles," strongly criticizes Campbell's treatment of radiolaria in Moore's Treatise on Invertebrate Paleontology, and also contains a plate of new types of Visean radiolaria.

Mrs. M. Deflandre-Rigaud and G. Deflandre have published a paper on a forgotten species, *Diffugia? marina* Bailey, 1856 (Hydrobiologia, vol. 12, 1959, p. 299-307), and a preliminary note concerning the discovery of *Nannoconus* in the Upper Cretaceous near Paris (C.R. Acad. Sc., 1959, vol. 249, p. 2373-2374, II fig.). New species and varieties are associated with known species from the upper part of the Lower Cretaceous. A paper on this subject is also in press in Revue de Micropaléontologie. They have also listed all species of the ten published Series (Micropaleontology, vol. 5, no. 4, p. 503) under the title "Fichier Micropaléontologique Général,

Catalogue des Fiches des séries 1 à 10 (1943-1958). This Catalogue is available without charge, and may be requested from the Laboratory. In her paper "Sur quelques sclérites d'Holothurides de l'Oligocène moyen d'Innien, Holstein" (Rev. Micropal., 1959), Mrs. M. Deflandre-Rigaud described two new genera (*Elgerius*, *Dictyothurites*) and fourteen new species.

Jean Deunff has published a paper entitled "Microorganismes planctoniques du Primaire armoricain; l'Ordovicien du Veryhac'h, Presqu'île de Crozon" (Bull. Soc. Geol. et Minér. de Bretagne, ser. 2, 1958-1959) containing the descriptions of a number of species of Silurian hystrichospheres (nine of them new) and chitinozoa.

Among the foreign research workers who have visited the laboratory were: William R. Riedel (Scripps Institution of Oceanography), who carefully examined our radiolarian microfauna from the Visean of the Montagne Noire to compare it with his Devonian and Silurian microfaunas; Dr. Marek Doroszewski (Biological Institut, Polish Academy, Warsaw), working on the testacean Rhizopoda of Spitzbergen; and William R. Evitt (Jersey Production Research Company, Tulsa, Oklahoma). At the end of his European trip, Dr. Evitt spent several weeks studying many types and original samples of flagellates (siliceous and calcareous), dinoflagellates, and hystrichospheres, and had several profitable and fruitful discussions with Professor G. Deflandre concerning his own interesting and original ideas on the systematic relations between a number of Cenozoic and Mesozoic hystrichospheres and dinoflagellates.

UNIVERSITÉ DE DIJON

The Department of Geology of the Dijon Faculty of Sciences is continuing its micropaleontological investigations. Dean R. Ciry and M. Amiot carried on studies of fusulinids and especially, during this year, of specimens from Karakorum (Afghanistan). P. Rat has published two papers on the Upper

Cretaceous of the Cantabrian ranges: "L'extension vers l'Ouest du Crétacé supérieur à faciès basques" (C. R. Coll. Crétacé supérieur en France, Dijon, 1959, p. 523-533, 2 fig.), and "Les milieux urgoniens cantabriques" (B.S.G.F., ser. 1, vol. 1, p. 378-384, 2 fig.) and is now studying the Wealdian of northern Spain. J. P. Mangin has published a paper entitled "Données nouvelles sur le Nummulitique pyrénéen" (B.S.G.F., ser. 1, vol. 1, p. 16-30), on the Cretaceous-Tertiary boundary in this area (C.R. Coll. Crétacé supérieur, 1959, p. 445-447), and also on the foraminifera of Tertiary flysch. Mrs. M. Mangin has published a study on Recent foraminifera (mainly miliolids) collected by the French ship *Calypso* in the Gulf of Guinea ("Résultats scientifiques des campagnes de la Calypso, 1959, fasc. 4). She also revisited the Terquem Collection of Rhodes "Pliocene" sands. Miss M. Malapris is studying the Upper Cretaceous of Burgundy. Research for various "Diplômes d'Etudes Supérieures" are under way; others in press concern the Lias, and the Lower Cretaceous of Burgundy and the Alps.

COMPAGNIE FRANÇAISE DES PÉTROLES
(PARIS) (C.F.P.)

Four geologists comprised the staff of the Laboratory of Sedimentology in Paris during the first six months of 1959. The staff was increased to five during the second half of the year, consisting of G. Nouet, Head of the Laboratory, R. Lacassagne, his assistant, A. Fediaevsky, responsible for petrographic studies, and Mrs. Champeau (née Miss Garrot) and Mrs. Authier, both working mainly with foraminifera and ostracodes.

During 1959 the Laboratory staff dealt with the following topics: Northern Spain - A detailed survey of the Paleocene and Miocene through microfacies and microfaunas, begun in 1958; Portugal - A petrographic and sedimentary survey of the Paleozoic (Ordovician to Carboniferous) has been completed; and the Paleozoic of Guinea - Comprehensive surveys of the

petrography of numerous sections from the "Infra-Cambrian," Cambrian and Ordovician, have been made on behalf of COPETAO (Compagnie des Pétroles Total, Afrique Ouest), a subsidiary Company of the C.F.P. Quantitative technical methods of investigation have allowed the correlation of series which are nearly azoic and for the most part consist of sandstone, quartzites, silts, silty clays and indurated clays.

M. Nouet visited Guinea in May, 1959. Mrs. Champeau has carried on her study of the Jurassic of the Paris Basin on behalf of the Compagnie Française des Pétroles (Normandie); in addition, she has prepared a publication on the microfauna of the Lias for the Congress of Chambéry (April, 1960). In June, 1959, she attended a Congress of Micropaleontology in Germany. Progress has been made on the dating of the Triassic and Cretaceous wildcat wells of the Société des Pétroles du Senegal (S.P.S.). The most important result is that in the Balandine no. 1 wildcat well beneath lower Aptian beds with *Choffatella decipiens*, *Pseudocyclamina hedbergi* and *Daxia*, there was found a series that seems to be of Neocomian age (horizon from 3700 to 4100 meters).

COMPAGNIE FRANÇAISE DES PÉTROLES
(GIRONDE) (C.F.P.) (G.)

Mr. Dufaure has been assisted by Miss Fernet and Miss Sourdillon in carrying on the work of the Laboratory. The Company stopped field and drilling activity in the southwest of France early in 1959, so that the Laboratory could deal with revision work for several months. Important contributions have been made to the knowledge of Upper Jurassic and Lower Cretaceous stratigraphy. Miss Fernet and Miss Sourdillon worked mainly on free microfaunas, while Mr. Dufaure studied microfacies and coordinated stratigraphic investigations.

In May, 1959, it was decided to transform the C.F.P. (G.) laboratory of Bordeaux into a central laboratory for the whole Company. Mr. Sacal, working in the Algerian

branch, has been designated to be in charge of this new organization. The Central Laboratory is organized for all the local branches of the C.F.P.; reorganization of its activities have been necessary. The following were established in 1960: an X-ray section for clay-mineral studies; a palynology section to deal with stratigraphic problems of the African Paleozoic; and a micropaleontology section applying more specialized methods of study. The staff of the first two sections began their studies in 1960. In the third section, Miss Sourdillon is working on Mesozoic and Tertiary foraminifera and ostracodes and their ecology, while Miss Fernet assumes the study of Paleozoic foraminifera, ostracodes and conodonts. Both have studied at institutions already acquainted with these techniques. Mr. Dufaure will assist Mr. Sacal in the coordination of work between all sections; he has worked in palynology and in X-ray methods.

COMPAGNIE D'EXPLORATION PÉTRO-
LIÈRE (CHAMBOURCY) (C.E.P.) (G.)

The Laboratory of the Exploration Division has continued its work under the general supervision of Dr. Wolf Maync, ably assisted by Mr. F. Bernard. With regard to the study of the Dogger sections in the Paris Basin, and, in particular, of the company's Chailly field, the main emphasis is now solving the intricate problems of lithology and facies of the reservoir rocks. This investigation, directed by Mr. J. C. Durand, has resulted in a comprehensive lithological-stratigraphical synthesis. Mr. M. Mathieu has concluded his sedimentological investigations of the Neocomian section drilled in the Paris Basin, and an analysis of the foraminiferal faunas has led to a reliable subdivision of the sequence. This work is being carried out by Mr. J. Chevalier, who has just finished an extensive study of Lower Cretaceous foraminifera from southern France, which he will submit to the University of Paris in order to obtain his "Diplôme d'Etudes supérieures." A paper entitled "Les Ostracodes du Crétacé de Champagne Humide" has been

presented by Mr. E. Grosdidier for his diploma. Mr. J. Bellon has studied in detail the microfacies of the complex Upper Cretaceous-Tertiary series of the Camargue, southern France, as well as the Jurassic of the Béziers area. Mrs. D. Guichard, who is head of the Saharan sector of the Laboratory (St. Germain-en-Laye), has worked on the rich foraminiferal faunas of the Moscovian and Namurian (Reggane and Tinrhert basins) and has studied thoroughly the microfacies of the Paleozoic section (Carboniferous and Devonian). A very detailed zonation of the Lower Paleozoic sequence by means of ostracode associations has been successfully developed by Mr. Le Fèvre, who has now left C.E.P. to join S.N.P.A. His work is being continued by Miss Ducazeaux. Before leaving France, in order to take a teaching post at the University of Phnom Penh, Mrs. Remack-Petitot submitted a detailed report on the conodonts used for stratigraphic determination in the Sahara concessions.

Apart from his activities as supervisor and consultant, Wolf Maync has examined a great number of samples from different parts of the world, forwarded by colleagues and students for identification. At present, he is engaged in a study of the genus *Orbitopsella*, based on original and topotype material. The following papers have been published since the last report: "Deux nouvelles espèces crétacées du genre *Pseudocyclammina* (Foraminifères)" and "*Martiguesia cyclamminiformis* n. gen., n. sp., un nouveau genre des Lituolides à structure complexe" (Rev. Micropal.); "*Torinosuella* n. gen., eine mesozoische Gattung der lituoliden Foraminiferen" (Eclodge Geol. Helv., vol. 52, no. 1); "Bemerkungen zur Systematik der Lituolidae" (Pal. Zeitschr., vol. 33, no. 4); "Biosphères et analyse morphométrique des espèces jurassiques du genre *Pseudocyclammina* (Foraminifères); Part. I - *Pseudocyclammina lituus* (Yokoyama) (Rev. Micropal.); "On some larger arenaceous foraminifera from the Liassic limestone section of Monte Baldo,

east of Lago di Garda, Italy" (Riv. Ital. Pal., 1959, 1959, no. 4). A paper on a biometrical study of *Pseudocyclammina jaccardi* has been submitted for publication in the "Revue de Micropaléontologie."

SOCIÉTÉ DE RECHERCHES PÉTROLIÈRES DANS LA RÉGION PARISIENNE (PETROREP)

The Laboratory was mostly occupied with the study of Dogger and Lias microfacies. Several microfacies catalogues were completed after the study of thin sections. Microfacies photologs were also made for the producing wells of the Coulommès field, and stratigraphic markers defined in the upper Bathonian. Lias stratigraphy was precisely determined after the discovery of ammonite faunas in the cores of wells CR-I and BE-I.

CENTRE D'ÉTUDES ET DE RECHERCHES DES CHARBONNAGES DE FRANCE (CERCHAR)

The staff of the section headed by Dr. B. Alpern, was recently increased. It now comprises four technical assistants and three graduate students preparing doctorate theses. In addition to the normal work in progress on the microspores of different coalfields, new studies have been undertaken. A study of the megaspores of the Lorraine coalfield is now being carried out. A method of macerating Carboniferous shales and sandstones is also under development, and is being applied to the study of the Stephanian of the St. Etienne coalfield. Quite satisfactory results have been obtained in the Lorraine coalfield in the correlation of coal seams through the study of microspores. The laboratories of palynology and petrography of CERCHAR are closely associated.

SOCIÉTÉ ESSO DE RECHERCHES ET D'EXPLOITATION PÉTROLIÈRES (ESSO R.E.P.)

The Paleontological Section and the Geological Laboratory, headed by Mr. J. Magné, devoted most of their time this past year to the routine study of Esso R.E.P.'s exploration and development wells in the Aquitaine

Basin. Special studies were made on the stratigraphy and facies of the Lower Cretaceous. This work is mainly on the development of reef and clastic formations in the Albian and Aptian.

Messrs. F. Dalbiez and G. Malmoustier presented "Microfauna of the Upper Cretaceous of the Aquitaine" at the 84th National Congress of the Sociétés Savantes in Dijon. Papers dealing with the microfauna and microfacies of the Liassic of the Aquitaine Basin and of the type locality of the Toarcian will be presented at the 85th Congress of the Sociétés Savantes by Messrs. J. Magné and G. Malmoustier. Mr. Malmoustier submitted his detailed study of the microfauna and boundary between the Oligocene and Miocene in the western part of the Aquitaine Basin to the University of Bordeaux for a Diplôme d'Etudes Supérieures.

Upper and Lower Cretaceous flysch sections in the northern edge of the Pyrenees were studied by Mr. J. Magné. A rich microfauna enabled him to make zonations of the different stages of these formations, which agree fairly well with the Mediterranean series. A study of the microfauna and microfacies of the Jurassic and Cretaceous of the Languedoc by Messrs. C. Gaudin and J. Magné is in progress. The Paleontological Section of the Company was represented by J. Magné at the European micropaleontological meeting held this year in the southwest part of Germany.

SOCIÉTÉ NATIONALE DES PÉTROLES D'AQUITAINE (S.N.P.A.)

The Laboratories in Pau are now divided in two branches; one, for routine work corresponding to the drilling and field stratigraphic activities in Aquitaine, is under the direction of M. Deloffre and his assistants, Miss Billiard and Mrs. Blanc. The second branch, which was created on July, 1959, is a large "Centre de Recherches sédimentologiques," the direction of which has been given to Mr. Kulbicki; the Center is, in fact, a laboratory with

two main divisions: one, for mineralogy, with M. Kulbicki and M. Elloy; and the other for the various phases of micropaleontology. In these subdivisions, microfaunas and microfacies are most important for stratigraphic purposes; working on them are MM. Rey and Dalmas and MMmes. Marot, Aubert, and Pantaloni. The Ostracoda section is under the direction of M. Oertli with the assistance of M. Marot and Miss Delteil. A palynology section under the direction of M. Deunff has been added to the Center. In the future, the research center will be a large laboratory in which all problems of stratigraphic micropaleontology and sedimentation will be taken into consideration; the questions under study will concern all the regions in which S.N.P.A. will explore for oil.

The activities of the stratigraphic laboratory in Montélimar continued throughout 1959. J. Faber showed that Neocomian microfacies of "Les Pilles" (Drôme) are different than the Ardèche microfacies; they are composed of pelagic sediments with numerous radiolaria. A suballuvial geologic map of the Montélimar regions was compiled from C.N.R. well data. Moreover, he continued his work on the Barremian-Bedoulian problems in Ardèche.

J. Maillard studied the Jurassic to Tertiary stratigraphic series of the Ventoux region; Leenhardt subdivisions in Urgonian facies were found to correspond to typical microfacies. Miss F. Leduc carried on her studies of the Lias and Jurassic in Ardèche and Drôme and good stratigraphic logs have been established, and correlation tables compiled. Oxfordian shales were found to be rich in foraminifera. D. Fournié began a study of the Miocene series of the Nyons basin. Characteristic microfacies and microfaunas were found for each stage.

Upper Cretaceous zones have been recognized in Villedieu and Bouchet wells; and Neocomian and Jurassic zones in Savvase, Marsanne and Villeneuve-de-Berg drillings.

SOCIÉTÉ ANONYME FRANÇAISE DE RECHERCHES ET D'EXPLOITATION DE PÉTROLE (SAFREP)

During 1959, the activity of the geological laboratory of SAFREP-NORD in Dijon, under the direction of P. L. Allard, has been concerned with the study of sediments from wells in Auxerre-Joigny (Zone I) and the Dijon-Besançon (Zone II) areas. The staff of the laboratory consists of one geologist and two laboratory assistants. About 2600 thin sections and 1200 washed samples were prepared and examined.

In collaboration with J. Sigal, P. L. Allard has published a paper on the Cenomanian of Pontailler-sur-Saône. He has studied the occurrence of Liassic Ostracoda, and made an atlas of the microfacies of the Upper and Middle Jurassic (Zone I); he is now working on that of Zone II. He particularly studied the lacustrine (*Microcodium*) and conglomeratic Tertiary to the south of Dôle (Zone II). The laboratory of Dijon will be moved on the first of June, 1960, to Algiers.

During 1959, the laboratory of the southern division of Bayonne carried on its routine work on samples from two wells and surface samples. Mr. P. Sauvan gave a detailed lithologic study of the Lower Cretaceous utilizing the petrographic classification of carbonate rocks of R. L. Folk (1959). This study provided a means for distinguishing between various local sedimentary sequences; it was continued during 1960 by Miss E. Vincent using field data from the northern Pyrenean border and the Spanish "Pays Basque" Cretaceous.

RÉGIE AUTONOME DES PÉTROLES (R.A.P.)

The paleontologic and stratigraphic division of the Central Laboratory at St. Gaudens consists of four geologists, P. Durif, A. Artieres, A. Delaval and E. Szöts. During 1959, the staff continued its routine work on field and well samples from the various concessions in France and the Sahara.

In eastern Aquitaine, the principal efforts were directed toward the Jurassic-Cretaceous boundary and a zonation by microfacies of the Lower Cretaceous; these problems were worked on by P. Durif and L. Fournier. On the occasion of the "Colloque sur le Lias français," which was held at Chambéry in April, 1960, a paper entitled "Le Lias en Aquitaine orientale" was presented by A. Artieres and P. Durif. E. Szöts pursued his work on the Paleocene and Eocene of Aquitaine. Studies were also undertaken on field and well samples of the Tertiary formations of Limagne; a sparse microfauna, including Miliolidae and Ostracoda, was found. A detailed study of the microfaunas and microfacies of the Dogger of the Paris Basin was continued by Mrs. L. Monteil and A. Artieres; several faunal zones were distinguished, and good correlations obtained.

In the Sahara, micropaleontological zonation was obtained in the Carboniferous of the Fort Polignac basin by P. Durif and A. Delaval. The principal results were summarized by P. Durif in a paper entitled "Observations micropaléontologiques (Foraminifères) sur le Carbonifère marin du Bassin de Fort Polignac" (Soc. Géol. France, Bull., ser. 7, vol. 1). Stratigraphic correlations were carried on for the Silurian and Devonian utilizing an abundant macrofauna, especially rich in brachiopods and graptolites, collected from numerous well samples and identified with the aid of specialists.

COMPAGNIE DES PÉTROLES FRANCE-AFRIQUE (COPEA)

The Company, founded in 1957, began its laboratory work in 1958. A district laboratory, located at Nyons (Drôme) was at first headed by Mr. Hamaoui and then by Mr. Micholet, under the direction of Mr. Riche, head of the "Bassin Rhodanien" section, and by Ch. Glintzboeckel.

This district laboratory is chiefly engaged in settling subalpine Jurassic microstratigraphic problems. Together with routine activity,

specialized work is being done on Lias by Mr. J. Micholet; on the Dogger by Mrs. J. Micholet, and on the Callovian-Oxfordian ("Terres Noires") by Mr. B. Prestat. These three studies will be the subjects of third cycle theses under the direction of Prof. Cuvillier.

The main laboratory of COPEFA was established in Marseille at the beginning of 1959; it is directed by Mr. Ch. Glintzboeckel, assisted by Mr. B. Prestat, Mrs. V. Aulagnier and Miss Y. Leclercq. Their task consists of microstratigraphical surveys of the geological series in the concession areas of this Company.

During, 1959, research work was principally concerned with the sub-alpine Jurassic; its microfauna is rather poor, but becomes progressively richer at the 250-mesh sieve size. Microstratigraphy is chiefly based on the very sparse microfaunas of sieved specimens and on thin sections. Thus, *Globochaetae* have been found from the Upper Jurassic, primitive *Globigerinas* especially from the Oxfordian, and *Vidalinas* from the Liassic, all as free specimens. The Aquitaine and Jura Jurassic and Mesozoic series, as well as Paleozoic of the Sahara, are also being studied.

A note on "La répartition des microfaunes à plancton et à Ostracodes dans le Crétacé supérieur de la Tunisie et de l'Est Algérien" was published by Ch. Glintzboeckel and J. Magné (Rev. Micropal., no. 2, Sept. 1959).

SOCIÉTÉ DES PÉTROLES DE VALENCE (DRÔME)

The Valence Laboratory, employing only one engineer, has continued working on a stratigraphical survey of the drillings in the Rhône Valley.

JEAN CUVILLIER
Laboratoire de Micropaléontologie
University of Paris

NORTH AFRICA



JEAN MAGNÉ

MOROCCO

SOCIÉTÉ CHÉRIFIENNE DES PÉTROLES (S.C.P.)

During the year 1959, the activity of the geological laboratory of the S.C.P. dealt mainly with the study of well and surface samples from the Rharb-Prérif areas and from southwestern Morocco. A total of 5395 thin sections and 2178 washed residues were studied.

After general exploration, a detailed stratigraphical study of the Mesozoic series of southwestern Morocco was undertaken by Miss E. Vincent and Mr. L. Brun. Microfacies with *Pseudocyclammina*, *Valvulinella*, *Trocholina*, *Iberina* and *Choffatella* make interesting stratigraphic markers and permit correlation of the various sections. The chemical analysis of rocks, and in particular the measuring of percentages of carbonates, carried out by the Laboratory of Physics and Chemistry, was also used for correlation of the southwest Moroccan wells. Interesting results were also obtained in comparing measurements of porosity in microfacies and chemical composition of reefal dolomites of the Argovian of Djebel Jeer and Djebel Kechoula.

SERVICE GÉOLOGIQUE DU MAROC

A micropaleontological laboratory was created in Rabat during 1959 for the Geological Survey of Morocco, under the Ministère de l'Economie Nationale. Mr. L. Hottinger, who was assistant to Professor Reichel in Basel, has been engaged to direct the laboratory. This new

laboratory works on samples collected by the geologists of the Survey; Mr. Hottinger works primarily on larger foraminifera. Mr. J. Magné has collaborated with the Survey for several years, studying the smaller foraminifera from the Cretaceous and the Tertiary of the Riff.

ALGERIA

UNIVERSITY OF ALGIERS

The Center of Stratigraphy and Sedimentary Petrography, directed by Professor R. Laffitte, completed numerous works during 1959.

Miss D. Noël carried on her research on coccoliths of Paleozoic and Mesozoic (mainly Jurassic) age. Her thesis for the doctorate, "Study of the coccoliths of Jurassic and Lower Cretaceous," has just been published. A biometric study dealing with populations of *Nannoconus* indicated that the material under study consisted of a single polymorphic species, *Nannoconus colomi* Lapp. The importance of coccolithophorids in petrography was shown in both marls and in the phenomena of phosphatization. The third part of this work was devoted to the study of the test of calpionellids.

A thesis for the doctorate by Mrs. H. Manivit, "Contribution to the study of the Coccoliths of the Eocene," is now in press. It deals with Algerian samples in addition to some samples from France. Nine centuries have been described as new. A stratigraphic chart of the observed coccolithophorids was made, permitting interesting although hypothetical conclusions to be drawn; our knowledge of this group of microfossils is still limited. This work on the Eocene coccoliths allowed Miss Noël to study a great number of discoasters. A revision of the genus *Discoaster* was made and shall be published shortly. It includes both synonymies and the stratigraphic distribution of that genus, and indicates that some discoasters are useful index fossils. A key is included which facilitates the specific determination of these calcareous corpuscles.

The study of Cretaceous material undertaken by Mr. C. Caratini is going well. It has already provided interesting results which will be published. Miss Noël and Mr. Caratini are also studying the fine structure of fossil coccolithophorids with an electron microscope.

Mrs. F. Gautier-Bernard continued her studies of the radiolaria from different horizons of marls of upper Albian to lower Cenomanian age from eastern Algeria. This important work was presented as a doctoral thesis. Its title is "Contribution à l'étude des Radiolaires du Crétacé d'Algérie." The richness of the sample and the perfect state of preservation of radiolaria enabled her to describe 108 species (96 of which are new) and 43 genera (2 of which are new), from the Sphaeroidea (9 genera and 21 species), Discoidea (22 genera and 60 species) and Nassellaria (12 genera and 27 species). This fauna shows a relationship to that of the Italian Cretaceous, not only in the similarity of genera and species but also in the dimensions of individuals and their general aspects.

Mr. Y. Reyre undertook a palynological study of the Jurassic and Cretaceous series of the Sahara. He observed a very abundant microflora from the Upper Jurassic of southern Tunisia, where the genera *Matonisporites*, *Concavisporites* and *Cyatheidites* are common. The individual forms, as well as the floral assemblages are similar to those of the English and Belgian Wealdian. Reyre has also found several levels with pollen from the upper part of Lias and the middle part of the Lower Cretaceous. These discoveries are of great interest, particularly that relating to the Lias, which is generally very poor in microfloral content, and from which he reports the presence of the genus *Cicatriculites*. In general, the observed microflora are largely composed of ornamented spores such as *Leptolepidites*, *Concavisporites*, *Trilobosporites* and *Lycopodiumsporites*.

Mr. J. Emberger, in his doctoral thesis entitled "Esquisse géologique de la partie orientale des Monts des

Oulad Nail," presented a careful study of the Mesozoic series outcropping in this region of the Saharan Atlas. Measurement of the thicknesses of the various series indicated the important part played by the movements of subsidence in this basin. These movements allowed the accumulation of more than 6,000 meters of sediments in waters which were consistently either marine and shallow (50 meters at the greatest) or continental. Mr. Emberger also continued his research on the calcareous algae of North Africa. He has in press a work on the forms he observed in the Ordovician of the Sahara (*Dimorphosiphon*, *Vermiporella*), in the Carboniferous of the Colomb-Béchar basin (*Koninckopora*, *Beressellae*, *Ungdarella*, *Girvanellas*) and in the Upper Permian of south Tunisia (*Mizzia*, *Eogoniolina*, *Gyroporella*, *Girvanellas*, *Permocalculus*, *Gymnocodium*, *Solenopores*). After this will come a second volume which will include the description of fossil calcareous algae of the Mesozoic, in particular those of the Lias, the Upper Jurassic and of almost all stages of the Cretaceous. Emberger has in particular studied the Charophyceae.

SOCIÉTÉ NATIONALE DE RECHERCHE ET D'EXPLOITATION DES PÉTROLES EN ALGÉRIE (S.N. REPAL)

The geological laboratories were primarily engaged in petrographic and sedimentologic studies, owing to the development of the oil fields of Hassi Messaoud and Hassi R'mel, and to research on the Cambro-Ordovician and the Triassic of the Sahara. These studies were made by Mrs. Gassier, Mr. Bertrand, Mr. Moreau and Mr. Caye, a new laboratory geologist. The paleontological work of Mr. J. Deumié and Miss Bazoche was with Paleozoic microfacies, the microfauna of the Carboniferous of Fort-Polignac, and conodonts of the Sahara.

The palynological section, with Mr. E. Kossenko in charge, carried on research on spores of the Saharan formations, mainly of upper Paleozoic and Mesozoic age. The most interesting result was the discovery

of typical Moscovian associations in several wells in the northern part of the Sahara, dating continental levels previously poorly known and allowing accurate correlations. These associations include thirteen rather abundant forms, including *Leiotriletes adnatoides*, *L. adnatus*, *L. gulaferus* and *Calamospora pedata*. Palynologic research allowed determination of the stratigraphy of the lower part of the "Continental Intercalaire."

COMPAGNIE FRANCAISE DES PÉTROLES (ALGÉRIE) C.F.P.(A.)

During 1959, the staff of the stratigraphic laboratory of the C.F.P.(A.) was composed of the following geologists: Mr. V. Sacal, chief of the laboratory, Mr. Rouge, his assistant, Mr. Thouvenin and Mr. Lehmann, petrographic geologists, and Miss M. C. Deny, who was interested in Mesozoic microfacies.

Petrographic and micropaleontological studies were carried out on the Devonian and Carboniferous series of Fort Polignac region. The works dealt primarily with the Carboniferous for presentation at the Colloquium of September, 1959. The petrographic studies of the Cambro-Ordovician were continued in connection with the development of Hassi-Messaoud field.

The micropaleontological study of two exploratory wells in the northern Sahara, Ph. 1 and Li. 3, has led Miss Deny to re-examine some Mesozoic correlations and to revise, in older wells, several tentatively established stage boundaries, especially the Jurassic-Cretaceous boundary; new studies of Ostracoda may permit more accurate determinations. This year the laboratory began a study of the conodonts from the Saharan formations.

COMPAGNIE DES PÉTROLES D'ALGÉRIE (C.P.A.)

During 1959, paleontological and palynological studies were made of Mesozoic and Paleozoic fossils from the Algerian Sahara under the direction of Dr. A. J. Whiteman. A general zonation of Mesozoic rocks based on spores and pollen

has now been established by Mr. L. Nijssen. Seven zones have been recognized over a wide area in diverse depositional environments.

Research has been continued on hystrichospheres, in search of a key to the zonation of Lower Paleozoic rocks. Mr. F. Calandra began an investigation of the Chitinozoa, which has yielded promising results. A study of more than 400 Ordovician and Silurian graptolites from wells and surface sections has been completed by Dr. Whiteman.

DIRECTION DE L'HYDRAULIQUE ET EQUIPEMENT RURAL (D.H.E.R.)

There were no changes in the staff of the micropaleontological laboratory of the D.H.E.R., directed by Miss C. Pinard, during 1959.

The study of Eocene and Senonian faunas of Oued Rhirh in the Algerian Sahara, has been reopened and completed, using data from three new wells: Sidi Mahadi, in which the fauna was particularly rich; and M'Rara and El Hadjira, where the microfauna has indicated a greater depth for the Eocene and the upper Senonian. It appears that there is a syncline in this region even affecting the Mio-Pliocene.

A comprehensive study of the Quaternary fauna of the Mitidja and of the outskirts of Algiers has been undertaken by Mr. F. Villa of Milan (Italy). Miss Pinard has recently undertaken a study of the brackish-water diatoms collected in Quaternary formations of the Hoggar by Mr. L. Lessard, geologist of the D.H.E.R., and Mr. Rognon, geographer. This study will form the subject of a publication.

TUNISIA

SOCIÉTÉ DE RECHERCHES ET D'EXPLOITATION DES PÉTROLES EN TUNISIE (S.E.R.E.P.T.)

Drilling activity, during 1959, was primarily concerned with Paleozoic oil problems. These series have been exhaustively studied by Mr. Rabaté, Mr. J. Bonnefous and Mr. Macoin.

A study of the Cambrian permitted the establishment of satisfactory sedimentary correlations between the various wells, and has shown the existence of unconformities and thrusts within this system.

For the first time, a Cambrian fauna has been found in Tunisia; unfortunately, it consists of enigmatic fragments. The Ordovician has provided good sedimentary and faunistic references, allowing detailed correlations. In the Tremadoc, a beautiful fauna of Lingulas has been found. The Llandeilian proved to be rich in graptolites, trilobites and lamelibranchs. Oolitic ferruginous and chloritic levels found in the Arenig and the Caradoc have formed the subject of a careful petrographic study. A fauna of graptolites, abundant both in number and species, allowed exact dating of the Gotlandian series.

A study of the fauna and microfauna of the Devonian continued during the year, again demonstrating the stratigraphic value of the Ostracoda. A work of synthesis was undertaken on the Permo-Triassic series of south Tunisia, allowing correlations with the equivalent series encountered in Libya. Studies of the Jurassic of south Tunisia resulted in the distinguishing of the different sedimentary units. A study of microfacies and microfauna (particularly the ostracodes) established correlations between the various wells and field sections of south Tunisia.

A new young laboratory geologist, Miss M. Corfdir, student of Professor Cuvillier, was added to the staff in December, 1959.

JEAN MAGNÉ
*Esso-Rep
Bégles (Gironde)
France*

PERU



EDWIN T. ASHWORTH

This will be your present correspondent's final news report. He has accepted a transfer to Esso Standard (Guatemala) Inc., and after biennial vacation in the United States will be located in Guatemala City, Guatemala, where he will head the paleontological laboratory to be established there. Mr. R. E. Malloy of International Petroleum (Colombia), Ltd., Bogotá will replace your correspondent as head of International's Paleontological Laboratory in Talara and also has accepted to serve as your correspondent from Peru. Micropaleontological news in Peru concerns mainly the activities of oil company paleontologists located in the north-western part of the country.

EMPRESA PETROLERA FISCAL (E.P.F.)

EPF has moved its paleontological laboratory from Zorritos, a few kilometers south, to their current operating base at Los Organos. Federico Seminario is head of the laboratory and is engaged primarily with routine well correlations. EPF purchased basic equipment for conducting spore and pollen investigations some time ago, and Mr. Seminario is continuing preliminary work of this type.

INTERNATIONAL PETROLEUM COMPANY, LTD. (I.P.C.)

There have been a number of personnel changes in the laboratory at Talara. Mr. C. L. Wilmott was moved to Talara from El Alto (former headquarters of the Compañía Petrolera Lobitos) and the small laboratory which had been in operation there was closed. Mr. R.

W. Phillips, the other member of the El Alto paleontological staff, returned to England to work toward his doctorate and at last report had received his degree. He accepted employment with the Shell Group, and was temporarily stationed at the Hague. Mr. T. L. Liebetrau returned to the United States and Mr. J. A. McCormick joined the Talara staff on transfer from International Petroleum (Colombia), Ltd., Bogotá. Your correspondent, as previously mentioned, has accepted a transfer to Esso Standard (Guatemala) Inc., and Mr. R. E. Malloy of International Petroleum (Colombia), Bogotá, will head the Talara laboratory. Following these changes the Talara paleontological staff will then consist of Mr. R. E. Malloy, Mr. Fernando Zuñiga, Mr. J. A. McCormick, Mr. C. L. Wilmott and Mr. Elias Aliaga who was recently transferred from Well Geology to the Paleontological Section.

Micropaleontological work in the Talara Laboratory consists primarily of paleontological determinations on well samples from current drilling wells and studies pertaining to local biostratigraphic problems. In 1957, International acquired fifty percent interest in, and became the operator of, the concessions of the Compañía Petrolera Lobitos located to the north of Talara. Since that date the laboratory has directed much of its effort to studying the stratigraphic problems in the Lobitos and El Alto areas and in attempting to extend

correlations into these areas. Mr. Fernando Zuñiga has been working mainly with exploration samples from eastern Peru and has encountered some interesting Cretaceous foraminiferal faunas (principally arenaceous), as well as ostracode and charophyte faunas. The stratigraphic section which he is studying extends from Ordovician(?) to Recent. Your correspondent sent in a short note on the occurrence of *Globotruncana ventricosa* in Peru (Micropaleontology, 1959, vol. 5, no. 4) as recorded from some core samples of Maestrichtian age from a well drilled in the Sechura Desert. Previously, *Globotruncana ventricosa* has been reported from Mexico, Trinidad and Colombia and its occurrence in Peru extends its geographic range southward in the Caribbean area.

Although the Talara Laboratory has been engaged mainly in foraminiferal studies for many years, it will soon be equipped for spore and pollen investigations. Mr. R. E. Malloy will be in charge of the palynological work.

PERUVIAN PACIFIC PETROLEUM COMPANY

Peruvian Pacific (Richfield subsidiary) has just recently established a paleontological laboratory in Negritos, a few kilometers south of Talara. Mr. W. T. Rothwell and Mr. Wayne Elliott have arrived from California and are in charge of the paleontological work.

COMPAÑIA PERUANA DE PETROLEO "EL ORIENTE"

"El Oriente" (joint German and Peruvian company) operates in eastern Peru and until recently was the only company with a paleontologist located in that area. However, according to latest reports, Mr. Eric Blissenbach, who has been in charge of Oriente's paleontological work for a number of years, returned to Europe and was replaced by Dr. Wolfgang Reinecke. Dr. Reinecke has also returned to Europe and it is reported that "El Oriente" does not have a paleontologist in eastern Peru at present. Dr. Reinecke made some interesting correlations using charophyte zonations, which we understand he plans to publish.

OTHER NEWS

Dr. and Mrs. Gunnar Erdtman, of the Palynological Laboratory, Stockholm, Sweden, stopped for a short visit in Talara enroute home from a conference in Brazil, at which Dr. Erdtman was a lecturer. He also showed us some of his beautiful colored spore and pollen slides and gave a short lecture.

Dr. Viktor Petters of International Petroleum (Colombia), Bogotá, also paid the laboratory a visit during a business trip to Talara.

EDWIN T. ASHWORTH
International Petroleum Company, Ltd.
Talara, Peru

Directory of correspondents

The following list of correspondents is presented for the benefit of those who wish to submit news items for publication in this quarterly. Contributors should send such news items to the correspondents reporting for their own areas. Manuscripts of papers submitted for publication should *not* be sent to correspondents. They should be submitted to: Department of Micropaleontology, American Museum of Natural History, Central Park West at 79th. Street, New York 24, N.Y.

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